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BULLETIN

OF THE

Scientific Laboratories

OF

DENISON UNIVERSITY.

EDITED BY

W. G. TIGHT, M. S.,

DEPARTMENT OF GEOLOGY AND NATURAL HISTORY.

VOL. V.

WITH TWENTY PLATES.

GRANVILLE, OHIO, JUNE, 1890.

KUSSMAUL & SHEPARDSON,
PRINTERS, BOOKSELLERS AND STATIONERS,
Granville, Ohio.

EDITORIAL STATEMENT.

In presenting the Fifth Volume of the Bulletin to the public, it has been our intention to bridge over, as far as possible, the break which is the result of the change in the administration of the Geological and Natural History Departments. We take this opportunity to thank those who have contributed to our museum and otherwise encouraged the work of the departments. Obligations are expressed: To Prof. B. F. McKibben, for a collection of Lower Silurian fossils; to Mr. E. Clark, for a collection of minerals and lithological material from various points in the Rocky Mountains; to Mrs. Delano, for a large collection of shells, star fishes and numerous other zoological specimens; to C. J. Herrick and W. H. Cathcart, for much time and labor spent in identifying, labeling and arranging the Herbarium; to Prof. C. L. Herrick, for a large collection of minerals; to numerous scientific societies and persons who have contributed to our library; to others who have aided in various ways the work of the departments. but whose names may not appear, caused by change of the administration. We publish elsewhere the list of those persons and societies which give equal exchange of publications, but would ask the pardon also of any who may have been omitted from this list by mistake. As this issue is supported entirely by voluntary contribution we would mention our indebtedness for the larger part of the means to Hon. E. J. Barney, Hon. J. B. Thresher, Hon. E. M. Thresher, Hon. Albert Thresher, of Dayton; Prof. C. L. Herrick, of University of Cincinnati; Prof. A. D. Cole, Prof. G. F. McKibben, Prof. H. L. Jones and Prof. W. H. Johnson, of the Denison Scientific Association. We would also thank Prof. C. L. Herrick for his aid in planning the work and reading some of the proof sheets.

It is hoped that this volume will partly represent the original plan of the publication and that its scope may be extended as larger means are provided for the work.

II.

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III.

LABORATORY NOTES.

1. GERMINATION OF PHOENIX DACTYLIFERA.

(Presented to the Scientific Association, October 29th, 1889.)

At one of the meetings of the Scientific Association, early in April, some members of the society asked how the date seed (Phœnix Dactylifera), germinated; whether the shoot came from out the little groove in the seed, from either end or from the back, and if it was always uniform or depended on the position of the seed.

During the informal discussion which followed several opinions were offered, but, as no one seemed positive about the matter, a committee was formed to study into the subject and report at some future meeting. I was chairman of the committee, and failing to find any satisfaction from numerous books consulted, determined to find the desired information by means of a series of practical experiments.

In a box of loose soil composed of sand, loam and leaf mold, I planted six well developed, healthy date seeds. They were planted in different depths of earth, ranging from 4 inches to 1½ inches from the surface of the box, and were each in a different position—one vertical, one horizontal, one inclined to the right and one inclined to the left and one each with the groove up and down, as seen in Plate A, *Fig.* 1.

The seeds were planted the first week in June, were kept in the sun as much as possible and watered with hot water. The 10th of August signs of life began to show themselves. By the last of the

month six slender, shining parallel veined linear leaves were waving gracefully above the soil. I let them grow in the hot sun until the 1st. of September, then I carefully removed the earth from around them and put them in a glass jar. The method of germination is illustrated in Plate A, *Fig.* 2.

In every case the radicle had come from the smooth side, even when it had to make quite a curve in order to turn its point into deep soil and the plumule springing from the convexity of the radicle starts upward. Thus proving that the germination is invariably the same, always rising from the center of the back of the seed and sending forth at the same time two growths, one downward, terminating in roots and rootlets, and the other upward, forming the leaf and eventually the tree proper. MRS. J. E. DIXSON.

[EDITOR'S NOTE.—We take the liberty to insert, Plate A, *Fig.* 3, a pen sketch after Sachs' diagram, of the cross section of the date seed I, and germination of the same, II and III, showing internal arrangement of plumule, &c.]

2. WINTER FLOWERS.

H. L Jones.

(Presented before the Scientific Association January 11th, 1890.)

The winter of 1889–90 will long be remembered for its extreme mildness. The effect on flowers was remarkable. Spring, summer and fall flowers were found growing side by side with one another. The following is a partial list of those blossoming in this vicinity in the winter months, with the date of each:

November	6.	*Pyrus malus.*
"	17.	Houstonia caerulea, L.
December	1.	*Sisymbrium officinale*, Scop.
"	1.	Achillea millefolium, L.
"	23.	*Taraxacum officinale*, Weber.
"	27.	Claytonia Virginica, L.
January	6.	*Viola tricolor*, L.
"	6.	Hamamelis Virginica, L. All winter.
"	6.	*Stellaria media*, Smith. "
"	6.	*Cerastium viscosum*, L. "
"	6.	*Capsella bursa-Pastoris*, Moench.
"	6.	Lepidium Virginicum, L.
"	6	*Draba verna*, L
"	6.	*Malva rotundifolia*, L.
"	11.	*Viola odorata*, L.
"	11.	*Acer*, (species ?) cultivated.
"	11.	Ulmus Americana, L.
"	25.	Salix discolor, Muhl.
"	25.	Salix (species ?).
"	25.	Houstonia caerulea, L.
"	25.	Symplocarpus fœtidus, Salisb.
February	15.	Erigenia bulbosa, Nutt.
"	15.	Claytonia Virginica, L.
"	22.	*Vinca minor.*

The Italics mark plants which have been introduced or are found only in cultivation. It is to be noticed the large per cent. they form of the number, being more than half. On January 3d, 1889, Phlox subulata, L. was found in blossom, but careful search this year failed to reveal any specimens until spring.

3. A CONVENIENT INJECTING APPARATUS.

By W. G. Tight.

(Presented to the Scientific Association, October 5th, 1889.)

There is a demand in every biological laboratory for some sort of an injecting apparatus. The syringe is good in its place, but when an experiment is to be performed in which it is necessary to know the exact amount of pressure, to have the pressure uniform and constant we must look to other means. To be sure, there are instruments constructed which meet this demand, but they are generally expensive and hard to obtain.

The mercury column has been utilized in various ways, but the volume required makes that also very expensive.

The bucket of water hung on a hook on the wall, with a tube leading to a pressure bottle below, is also good in its way and easily arranged and inexpensive, but no means is provided to regulate the pressure and as the bucket becomes empty the pressure gradually falls.

In the instrument about to be described the following benefits are to be derived: The expense is within a few dollars at the greatest; the pressure can be accurately regulated from zero to four pounds (or more, if a higher standard is used); the pressure is constant as long as there is any liquid in the upper flask; the pressure can be easily increased as injection advances; and requires no attention after it is once started, so that a difficult injection can be conducted by one person, as he can devote all his attention to his canula and the operation. It may stand on its own merits.

The following is the description of the instrument used in our laboratory, a drawing of which is presented by A of Plate A, *Fig.* 4.

The base board is 2x15 feet; the standard 2 in.x2in. 8ft., graduated to feet and half feet. Upon the standard is attached a small bracket by means of a friction clamp.

The shelf is braced to a small piece of wood one inch thick and two inches wide; to the lower end is attached a small metal band which clasps the standard; while the upper end is secured by a stiff wire bent as shown at E, (*a*, front view, *b*, side view), with the points of the wire inserted in the sides of the slide piece near its upper end and the wire passing around the standard.

Upon this bracket rests a gallon flask ; a glass tube passes through the stopper (which is of rubber) to the bottom of the flask. On the lower end of the tube is arranged a small valve (B) which is made by placing a short section of rubber tube which just fits the glass tube over the end of the tube and a little longer section of a little larger rubber tube over the first rubber section, a small glass cone is then made by drawing down a glass rod or tube. This small cone fits in the end of the glass tube and is kept from falling out by a small pin passed through the diameter of the rubber tube below it. This allows the free passage of the air into the flask, but stops the water from passing up the tube in case there should be any back pressure. The end of the tube should be ground and smooth and greased a little so as to make a water tight valve. At the lower edge of the flask a small hole is made with a round file and in this is inserted a rubber tube about eight feet long, which opens into the pressure bottle.

Another flask of the same capacity as the first is used as a pressure bottle.

The rubber stopper is perforated by three tubes which pass just through the stopper. The tube to which the long rubber tube is attached must not have an orifice more than a quarter of an inch in diameter, else air bubbles will pass back up the tube when the pressure reaches its maximum.

Another tube is bent, as shown in the diagram, so as to come along the side of the flask. This tube is filled half full of mercury and is graduated up and down from the zero point in half inch divisions ; then a half inch reading on either scale records an inch mercury column, equal to one half pound of air pressure in the pressure bottle. At the open end the diameter of the tube is diminished and it is curved a little to exclude dust.

The third tube bears a rubber tube, to which is attached a glass cross or metal piece, giving three outlets. To these are attached rubber tubes leading to the injection bottles. Three injection bottles are used, one for normal salt solution, one for red and one for blue gela-

tine, (or other coloring injections). All the rubber tubes are provided with thumb pinchers. The advantage of the three pressure tubes is obvious, as the normal solution may be used and then by closing the pincher leading to the pressure flask the pressure is all ready for the colored injections and, in case both colors are to be used at once, both injecting fluids will be under the same pressure.

Our injection bottles C, are made of clamp top cans, by drilling two holes through the top to one side of the clamp, a little larger than the glass tube to be used, thus allowing a rubber collar to be used around the glass tube and furnishing a movable and air tight union. The long tube which reaches to the bottom of the bottle is the one to which the canula tube is attached. If all unions are tight the flow of the liquid from the upper to the lower flask should force an equal bulk of injecting fluid from the injection bottles, less the amount of fluid re-vuired to produce the first pressure, with a single charging of the apparatus.

A saturated salt solution is found to work admirably as a pressure liquid. The pressure is regulated by shifting the friction bracket and the pressure is read from the mercury scale.

4. A SIMPLE SPIROMETER.

W. G. Tight.

(Experimented with before the Scientific Association, March 8th, 1890.)

The apparatus here described and figured on Plate A, *Fig.* 5, is one which was constructed for and used by the class in Practical Physiology. The apparatus was constructed for the determination of the vital capacity, supplemental, tidal and complemental air, also for experiments on the increase of vital capacity by regular exercise of the respiratory mechanism. The results were so satisfactory that it was thought that others might wish to use the same plan, as the construction is very simple.

A board about 10 in.x 16 in x 1 in. forms the base; at the center of one end is braced an upright piece 1 in.x 1½ in.x 28 in.; to this at the top is also bracketed an arm 1 in.x 1½ in. x 12 in.; a large stone jar is used to hold the water and rests on the base board; a large glass jar (in our instrument a zoology preserving jar), having a capacity of something over 4,000 c. cm., is graduated from the bottom up into 50 c. cm divisions by adding water and marking the different levels; after this is graduated, a small hole in made with a round file in the bottom of the jar and a rubber tube with a glass mouth piece attached; the jar is then suspended bottom side up over the water jar, (by three wires which pass around it), by a wire which passes through a small pulley at the end of the arm and then through another nearer the standard and having a weight attached to the end of the wire just equal to the weight of the jar; the rubber tube is provided with a strong thumb clamp.

To work the instrument, open the thumb clamp, press the air receiver down into the water jar as far as possible; then by suction draw the water up into the air receiver until it is full of water. The re-

ceiver now rests on the bottom of the water jar and enough water remains in the water jar to protect the open end of the receiver and exclude the air.

To get the vital capacity, fill the lungs with the largest possible inspiration, place the tube to the mouth, open the clamp and empty the contents of the lungs into the receiver, at the end of the greatest possible expiration, close the clamp, read off the volume of air in the receiver, from the scale.

When the first air is sent into the receiver from highly inflated lungs it is under some pressure which is about balanced by the weight of the water in the receiver, but when the water in the two vessels is at the same level, if more air is sent into the receiver it finds little or no resistence, as the weight then begins to act to support the weight of the receiver.

To determine the three factors of the vital capacity of the lungs, the experimenter should be seated and should time his regular respiratory movements and should use the receiver about half full of water in order to obviate suction or resistance as much as possible.

It was found by the use of this instrument that the vital capacity of the class was a little above the average and that by blowing the vital capacity regularly twice every day those students whose vital capacity was far below the average at the start, could be brought up to above the average in the course of two or three weeks. It is recommended as a simple, cheap, and convenient lung strengthener.

5. NOTES FROM THE PHYSICAL LABORATORY.

1. An Instrument for Rapidly Changing the Cell Arrangement of Large Batteries.

(Presented to the Denison Scientific Association, April 5th, 1890.)

One of the greatest difficulties in the way of the teacher of Physics who believes in the thorough application of inductive methods, is the great amount of time necessary for the systematic development of his subject. This difficulty meets both the lecturer and the laboratory director. It happens constantly, for instance, in a lecture course on electricity—and not infrequently in courses on other branches of physical science—that some question is asked that can be satisfactorily answered by even a moment's use of an electrical current of a definite strength and potential. But the demonstrator, not having just the right kind of current immediately available and being pressed for time, is met by this alternative: he may take five or ten minutes of time that he really needs for the demonstration of a more important point, to set up a battery, perhaps at the risk of wearing out the patience of his class, or, unwilling to make such a sacrifice, he may content himself with the unsatisfactory answer, that *if* he had time to do so and so, such and such a result would be obtained In either case he is likely to lose the attention of his class and fail to produce conviction in their minds. The laboratory director feels even more keenly than the demonstrator the need of having all the laboratory facilities completely and immediately under his control. Many an earnest laboratory student loses interest in his work because he is compelled to waste so much time in simply getting ready for each experiment or determination that he makes. There is great need of more and better regulating devices in physical lecture room and laboratories. The instrument shown in plan and elevation at the end of this article, Plate B, *Figs.* 1 and 2, is designed to supply one need, namely, an electrical current easily adapted to a wide variety of uses. It gives at a moment's notice a current of any ampere strength and voltage within a considerable range, by changing the arrangement of cells in a large

battery to any one of a great number of combinations. The instrument illustrated is adapted to control a battery of twelve, twenty-four, or some multiple of twelve cells.

It consists of a base *a*, of thoroughly seasoned wood or ebonite, upon which is fixed a double row of flat, rectangular pieces of brass, 1, 2, 3, etc., each two or three centimetres long, one centimetre wide and one half centimetre thick. Each is fixed to the base by two round-headed machine screws, *d* and *e*, which fit into holes bored nearly through the brass from the under side and tapped out to fit the screws. The plates are so placed that the spaces between the rows are of the same width as the spaces between single plates. All are of equal size except two, 12 and 13, at opposite ends of the upper and lower rows; these are twice as long as the others. The plates may be connected like the coils of a resistance box, by flat plugs of brass shown in end and side elevation at *b*, and *c*, *Fig.* 2. Binding screws are soldered on at that end of each row which terminates in a short piece of brass. From these wires lead current to any desired point. Each plate in the upper row is connected to the positive terminal of a battery of one or more cells and each corresponding plate in the lower row with the negative terminal of the same battery. Thus, plates 1 and 13 form the terminals of one battery, and 2 and 14 of another. The battery wires are firmly held by one of the two screws of each plate, as shown at *f*. It is well to glue strips of wood, *g g*, under the ends of the base so that the screw heads will not have to be countersunk. To show how connections are made, suppose the simple case where each brass plate is the terminal of a single battery cell. In *Fig.* 3 we see at *a*, how the plugs must be inserted to give an arrangement of twelve cells in series, at *b* the arrangement of twelve cells parallel, at *c*, the combination of six cells in series and two parallel, and at *d*, of three cells in series and two parallel. If the cells are of the Leclanchè type, each with an electromotive force of 1.4 volts and internal resistance .7 ohm, we would have in the several combinations

	a	b	c	d	
Electromotive force,	— 16.8	1.4	8.4	4.2	volts.
Internal resistance,	— 8.4	.06	2.1	.53	ohms.
Current with no external resistance,	— 2.0	23.3	4.	8.	amperes.
" " 1 ohm " "	— 1.8	1.3	2.71	2.74	"
" " 5 ohms " "	— 1.3	.27	1.04	.96	"

This table shows the range of power possible by a moment's ad-

justment of the instrument. If the resistances of the various pieces of electrical apparatus in the laboratory are measured, a moment's calculation will show just what arrangement will give the greatest amount of current, or any amount desired, with a certainty and precision that is very satisfactory. This increased precision is possible with so little trouble by the use of this cell-connecter that it is well worth one's while to gain it.

Larger batteries can be managed either with a similar instrument having a greater number of plates and connecting plugs, or by attaching to each pair of plates in the form described, a battery of cells, arranged in series or parallel, according as high potentials or heavy currents are most required.

Another form of the instrument has been tried. It is more easily made, but is less convenient in use. It consists simply of two rows of binding posts on a base. These are connected by short wires in various ways, for various combinations Two rows of metal contact points, each carrying a sliding switch which could be placed upon the next point of either the same or the other row, would also be a convenient form. By this method, however, there would be difficulty in securing good contact between points and switches.

This instrument is especially useful for a complete experimental proof of Ohm's law. A student with one of them, an ammeter and voltmeter, or in place of the last two, a tangent galvanometer having both low and high resistance coils, can verify the law for a large number of representative combinations in a wonderfully short time.

It has been found a great convenience in this laboratory to have one of them upon the demonstrator's desk, with a dozen open-circuit cells attached. These require no attention for six months at a time, are always ready for use and do not polarize seriously in the short time necessary for an ordinary lecture experiment. The "old reliable" of the laboratory, a ten-cell plunge battery, has been thrown out of employment since the advent of the cell-connecter. It is surprising how much can be done by the open circuit cells, with the aid of their powerful auxiliary.

It is hoped that it may prove as great a convenience in other laboratories as it has in this. Evidently it can be used with secondary batteries as well as primary. In this way it gives perfect control of very heavy currents.

2. A Simple Chronograph.

The apparatus illustrated on Plate B, *Fig.* 4, can be made in any laboratory, and is for many purposes a good substitute for an expensive chronograph governed by clock work. It consists of an electrical pendulum *a*, suspended on a steel knife edge, which makes and breaks circuit by carrying a platinum wire through a drop of mercury at *b*. The same circuit contains an ordinary telegraph sounder with a long bent wire attached, so that every depression of the armature makes a dot on a long strip of smoked glass, which can be drawn slowly along the table in front of it. A large turning fork, carrying a short piece of very fine wire as a stylus, makes a tracing, simultaneously, about one half a centimetre to one side. This fork is conveniently supported by being inserted into one end of a piece of wood *e*, which is hinged at *f*, to the table. The amount of pressure of the stylus is regulated by a wooden screw passing through *e*, and pressing against the table. If the pendulum is adjusted to beat seconds and vibrated through a rather large arc so that the sounder works with a sharp, short click, the period of the fork may be very accurately determined. The close agreement of a number of independent determinations indicates the accuracy of which the method is capable. This is shown in the following series of four successive experiments:—

Experiment.	Times.	Vibrations.	Vibrations per Sec.
1	8 sec.	440.7	55.09
2	6 "	330.2	55.03
3	6 "	330.6	55.10
4	5 "	275.1	55.02
Average number of vibrations per second,			55.06

If it is desired to measure any other short interval, having thus accurately determined the period of the fork, it is only necessary to stop the pendulum, so as to complete the circuit permanently, and then introduce a telegraph key into the line. Now the sounder will register accurately each time the key is depressed, and the time between any two depressions may be determined by counting the number of fork vibrations included between the dots corresponding to those depressions. If for any reason it is desired to have the seconds marked also, the key for the occasional signals must be included in a

shunt on the main circuit, connecting the wire at *b*, with the wire leading to the top of the pendulum. The sounder will then register both the vibrations of the pendulum and the signals of the key.

3. Scale Divider.

It is often convenient in the work of a physical laboratory to have the means of quickly dividing a given distance into a specified number of parts. For instance, paper scales divided into tenths and hundredths, having a total length which bears no simple ratio to any ordinary unit of length, are occasionally required. The device shown in *Fig.* 6, Plate B, will be found useful for this purpose. It consists of a large piece of heavy card board, upon which is drawn an equilateral triangle, with a series of lines connecting the apex *a*, to points in the base *b c*, that accurately divide it into one hundred equal parts. The sides of the triangle should be about one metre long, and it is best to make the base of exactly that length. It is not necessary that the other sides should be exactly equal to each other or to the base. It is well to have lines, (not shown in the figure,) drawn parallel to the base at intervals of two centimetres, through rather more than half the height of the figure, or else a parallel ruler so fixed that it will always be parallel to the base. The edge to be divided, which must not exceed a metre in length, is pushed up from the bottom of the figure, always parallel to the base, until it exactly includes the number of divisions to be made between its ends. The points at which the lines meet the edge may then be marked with a pencil or pen, and the graduation is made. If the lines are drawn with care, divisions as small as one millimetre may be made with considerable accuracy. It is most convenient to have the cardboard mounted upon a wooden frame and hung upon the wall. A swinging arm, pivoted at *a*, with one edge straight and coinciding successively with the dividing lines as it is moved across the figure, may be used as a ruler to mark the divisions more rapidly. A fine needle firmly inserted at *a*, and a ruler constantly pressed against it at one end, may be substituted for this swinging arm.

4. An Electrical Couple for Projection.

The device shown in Plate B, *Fig.* 5, may be used as a lantern or porte-lumiere attachment, to illustrate several important phenomena of

the voltaic cell. It consists of a small slip of sheet zinc, one centimetre wide and six long, a similar slip of sheet copper a little longer, held by two saw cuts across the edge of a piece of thin board *a*, two c.m. wide, ten long and one thick, as shown in the figure. Two similar couples should be prepared, one with zinc amalgamated, the other without. The upper extremities of the slips should be filed flat and kept bright, so that good electrical contact can be secured between them, by simply laying a little slip of sheet copper *d*, across the tops. In use the metals are immersed in a flat cell containing dilute sulphuric acid and projected with a lantern or porte-lumiere. The following are among the points that the couple is designed to illustrate :

a. The fact that although the hydrogen is given off at the copper plate, the action is really at the surface of the zinc. This is shown very prettily by the currents of zinc sulphate solution falling from the zinc. These currents are clearly seen by virtue of their high refractive power.

b. The effect of amalgamation. This is very satisfactorily demonstrated by comparing the appearance of a couple having its zinc amalgamated with that of a couple having its zinc unamalgamated. A good idea of the relative amounts of local and useful action may be gained by comparing the rates of evolution of hydrogen at the zinc and copper plates respectively.

c. Diminished battery action with increase of external resistance. This is shown by replacing the connecting slip by a little piece of gas carbon or thin platinum wire.

d. The effect of a depolarizing substance is shown by using fresh bichromate battery solution in place of the dilute acid. The non-appearance of hydrogen and the change in color of the liquid from orange to green, are the points to be noted. If the glass cell is divided into two parts by a thin partition of plaster of paris, so that the zinc may be on one side and the copper on the other, the complete action of any two-fluid cell, as the Daniel, may be shown.

e. *Fig.* 7 shows a couple in which the copper plate is fused into a small test tube so that currents may be compared quantitatively by the amounts of hydrogen which they liberate at the negative plate.

A. D. Cole.

A SPECIMEN OF HESPEROPHONA VESPERTINA, Bonap.

W. G. Tight.

On the 10th of December a specimen of this rare bird was killed in front of Academy Hall, by Mr George Osbun The bird was a male and was apparently alone and was feeding on maple seeds, which were very abundant under the trees in front of the building. While it was busily engaged at its noon meal it kept up a constant chirp like that of the Cardinalis virginianus and only sounded its charactesistic "*yeeip*" when it was disturbed and was in the trees.

As the bird is such a rarity for Ohio, having been identified but once before, as far as I can learn, (Ohio Geological Report, Vol. IV, p 313.) in the State and that in March, 1860, I have concluded to give a detailed description of the superficial characters of the specimen in hand.

It does not differ much from the descriptions of Baird, Jordan, Coues, Wheaton, and Herrick, (Bulletin, Vol I.), which I have before me, except in the amount and distribution of white on the wings, the length of the three outer primaries being equal and a few other minor points which will be observed by comparison. For the complete osteology of the species, reference is made to the article of Prof. C. L. Herrick, University of Cincinnati, in Vol. I. of the Bulletin of Denison University.

Hesperophona vespertina Bonap. Bird, Male. Feet short; tarsus less than middle toe; tel. .93; tra. .56; lateral toes equal; 3t. and 4t. 7; claws compressed 12; bill very large, greenish-yellow (not dusky at base), .75 long and 75 deep; gape .81; tip of upper mandible extending beyond and over the lower; body length 8.10; wing 4.25; tail 2.50; depth of tail notch .25; primaries much longer than secondaries, the outer three equal and extending to beyond the middle of the tail; secondaries 6 in number and equal; tertiaries 3 in number and unequal; wing coverts covering half the extent of the wings; tail cov-

erts covering three-fourths of the length of the tail; nostrils covered by tufts of setaceous feathers and there is a tuft also at each side of the base of the culmen just in front of the eyes, with the setæ directed downwards and forwards. Coloration: The setæ and feathers at the base of the bill; crown; primaries; primary upper coverts; proximal half of the quills of the secondaries and tertiaries; proximal half of the quills of the inner half of the greater upper coverts; outer half of greater upper coverts; median and lesser upper coverts; twelve rectrices; upper tail coverts; and tibia black. From the black of the head the color shades rapidly into a deep brown and this to olive brown. The shading becomes more olive and finally a bright yellow on the rump and the under tail coverts. A broad band across the forehead and over the eyes; all the under wing coverts bright yellow. The distal half of the quills of the secondaries and tertiaries; distal half of the quills of the inner half of the greater upper coverts. white; with the outer margins of all the white portions of these feathers lined with a fine bright yellow margin.

It is interesting to notice how the white is distributed on the wings so as to make the greatest show with the least amount of white. The distal ends of the quills of the secondaries and tertiaries being white just to where the upper coverts begin and the distal ends of the greater coverts, being white just to where the median coverts begin, while the proximal ends of the white feathers which are covered are black. This combination of black, brown, olive, yellow and white makes a very beautiful effect. In the description, terms and abbreviations are after Coues, and measurements are in inches.

In connection with the appearance of this northern visitor it is worthy of notice that the winter has been unusually warm, vegetation just on the point of germination.

IV.

COMMUNICATIONS.

1. THE WAVERLY GROUP.

W. F. Cooper.

In continuing the list of articles on the Waverly of Ohio, under the direction of Prof. Herrick, the writer has endeavored to make the work as complete as possible, and it is hoped that the following pages may throw some light on the relation of the different horizons of the Waverly as exposed in Central and Northern Ohio. The identification of horizons has been made on organic evidence alone, except when conglomerates I and II were exposed, when it would be impossible to misconstrue the relations. As has been stated, the object of the survey was to ascertain the relation of the different subdivisions of the Waverly in Central and Northern Ohio. With that end in view, sections were made in most of the counties in this formation from the southern part of Ashland County to Cuyahoga Falls, Summit County. Over considerable areas it was impossible to trace the transition owing to the lack of high vertical sections, but most of the main facts illustrating the sequence were discovered.

In giving the results, we desire to acknowledge indebtedness to Prof. Pike of Garretsville, Portage County, and Mr. J. E. Woodland of Wooster, for valuable information respecting localities. Before giv-

ing the results it may be convenient to give a brief synopsis of the horizons as represented in Central Ohio.

Sandy shales and freestone	30 ft.	III3.
Shales and freestone	100 ft.	III2.
Shale	5 ft.	III1.
CONGLOMERATE II		
Shale	7 ft.	II2.
Freestone	40 ft.	II1.
CONGLOMERATE I		
Shales	60 ft.	I5.
Shales, concretionary	30 ft.	I4.
Lower Berea Shales	180 ft.?	I3.
Berea grit &c.	100 ft.?	I2.
Bedford shale	40 ft.	I1.

As may be seen by this section, the strata are divided into three portions, the first lying below the Chester limestone in Fairfield Connty, but farther north under the Carboniferous conglomerate, the second portion lying between conglomerates I and II, while division I rests on the Huron shale in Franklin County, but in Cuyahoga County, the Cleveland and Erie shales are interposed. For a correct understanding of the relations of the divisions farther north, it will be necessary to give a brief summary of the subdivisions as represented in Licking County. The Bedford shale (I1) is well exposed at Central College, Franklin County, where it lies immediately upon the Huron shale. It is of a chocolate color and can be easily traced on account of that lithological peculiarity. Five feet above the base, the following characteristic species were found, *Macrodon hamiltonae*, *Leda diversa* and *Orthis vanuxemi*. Lying on this is the Berea grit (I2) which may be one hundred feet thick but absence of exposures renders it very uncertain Next in order is the Lower Berea shale (I3).

The stratigraphical relations of this portion of the Waverly have not been made out, but it may be 180 feet thick. Two fossiliferous layers are contained within this subdivision as far as known, the first being well exposed on Rocky Fork, three miles from Gahana, Franklin County. Only two species were obtained here, viz: *Orbiculoidea newberryi* and *Lingula melie*, which are very abundant at a considerable distance above this. In the same subdivision is another fossiliferous zone from which many specimens may be obtained by a patient collector. *Atripa reticularis*, *Strophomena rhomboidalis* and *Prœtus haldemuui*, with several other species, are found in this stratum. Resting on the

Lower Berea shale is the Upper Berea shale (I4), which is the most fossiliferous zone yet found in the Waverly of Central Ohio; it is well exposed at Moots' Run, Licking County, where over seventy species have been found; it is an excellent base to work from, as it extends from the Ohio river to Lodi, Medina County. Lying on this, and forming the top of division I, is the Waverly shale; the fauna of this portion is remarkable for not containing more than ten species of gasteropods and brachiopods among the thirty-five species which have been described from it. The typical locality for this subdivision is the quarry on Raccoon creek, near the Dugway, three miles west of Newark, Ohio. At the close of this period conglomerate I was deposited, which also inaugurated division II. This division is separable into two distinct portions. Subdivision II1, is the freestone from which most of the rock for building purposes is obtained; *Syringotheris carteri* and *Crenipecten winchelli* are characteristic species. Above this, and underlying conglomerate II, is a band of shale (II2) seven feet thick. *Allorisma winchelli* and *Sanguinolites obliquus* are characteristic species of this layer. At the close of division II, conglomerate II was deposited, the conditions attending the deposition of which were subject to fewer breaks than those accompanying conglomerate I, as shown by the fact that some of the fossils of II2 occur also in conglomerate II, and even somewhat higher, while conglomerate I contains not a single lamellibranch or other remains, except a few brachiopods. Division III is separated into three portions, the first being well exposed at a quarry one and one-half miles south of Newark, Ohio, where it is five feet thick and is easily identified by means of the conglomerate which underlies it. *Orbiculoidea pleurites* and *Allorisma consanguinatus* are characteristic species. The second part of division three (III2) is well exposed at the water works reservoir one mile north of Newark. It is here one hundred feet thick. *S. stiratiformis* and *Schizodus newarkensis* are characteristic fossils. Resting upon this and forming the top of the Waverly formation is about 25 feet of sandstone containing *Phillipsia serraticaudata*, *Spirifer keokuk*, and *Productus rushvillensis*, with several other forms peculiar to it. The theory advanced by Prof. Herrick, for the origin of these conglomerates and the different faunal representations accompanying them, is, that there were a series of oscillations greatest in Central Ohio and lessening in intensity as we go north. When the first upheaval took place the central Waverly area was raised up and conglomerate I was deposited, resulting in the

destruction of almost all the life. Again there was a submergence and the freestone of division II was deposited. In course of time conglomerate II was laid in the same way as conglomerate I had been, then the Waverly sea had a long period of rest during which over 130 feet of sediment was deposited It is the object of this paper to show how the different horizons were affected by such oscillations, and if the strata in the northern part of the state cannot be most satisfactorily correlated on such an hypothesis. For convenience of comparison the same numbers for the different subdivisions will be used as are given in the first section. The following section taken from Bulletin Vol. IV of Denison University, will give a correct idea of the strata as represented in Hanover Township, Ashland County:

Shales, *Phillipsia serraticaudata*,	20 ft.	III3
Freestone and shale,	100 ft.	III2
Conglomerate II,	3 ft.	
Shale, *Sanguinolites obliquus*,	5 ft.	II2.
Freestone.	27 ft	II1.
Conglomerate I,	18 ft.	
Waverly shale,	40 ft.	I5.
Concretionary shales,	30 ft.	I4.

As can be seen the portion above conglomerate I has undergone scarcely any change, but a few facts observed are perhaps worthy of notice. The part designated III2 is not as fossiliferous as at Newark, Ohio, although the different species are represented and occupy the same place as farther south. The layer above conglomerate II has almost entirely lost its lithological character and fauna. *Orbiculoidea pleurites* being the only species found that could be referred to III1, with that also occurs *Discina magnifica*, which is described beyond, some specimens of which measure 2⅛ inches in length. *Syringotheris carteri* is also found in this stratum, as that species occurs very rarely above conglomerate II in Licking County. It would seem to indicate that the barriers which held most of the species very closely in Central Ohio, were beginning to disappear. This, however, cannot be substantiated on stratigraphical grounds, as conglomerate II is as thick here as in Granville Township. The freestone or III1 of Licking County is almost ten feet less in thickness than farther south, and is not as fossiliferous as in Licking County. In the Waverly shale (I5) no species have been found which could be referred to its equivalent farther south, but its position between the nodule layer and conglom-

erate I is sufficient to indicate its presence. The nodule layer is well exposed here and is rather fossiliferous, at the same time, some of its species which are characteristic of that horizon in Licking County, do not occur here, and vice versa. It may be well to illustrate this point more clearly. At Moots' Run the characteristic species are *Spirifer marionensis*, *Phillipsia præcursor*, *Streblopteria fragilis* and *Pterinopecten cariniferus*, in Ashland County, Hanover Township. *Phillipsia præcursor* and several other more uncommon forms have disappeared and some new species have taken their place, as *Pterinopecten ashlandensis*, and *Leiorhynchus ? richlandensis*, while *Hemipronites cenistria* and *Spirifer ? tenuispinatis*, which are scarce at Moots' Run, are very abundant here. The concretionary zone is about 250 feet below the Carboniferous conglomerate in Licking County, while in Ashland County it is only 200 feet. At Wooster, Ohio, the following section was obtained along Christmas Run and in Reddigs Quarry, immediately north of the city.

Dark sandstone,	15 ft	III2.
Conglomerate II,	18 in.	
Freestone,	40 ft.	III.
Conglomerate I,	1 ft.	
Shales, &c.,	30 ft.	I5.
Concretionary shale,	30 ft.	I4.

The strata lying on top of conglomerate II are not very well exposed, but one species (*Discina magnifica*) which occurs in III1, in Hanover township, is found immediately over conglomerate II1. It would be impossible to draw any line between III1, and III2, so that the former will be considered a part of III2. The top of division two or II2, which is exposed in Ashland county, has no equivalent here, and II1 is sparingly fossiliferous. *Lyringotheris cartcri*, which is so abundant farther south, was not found at this place. The nodule layer can be very easily correlated with its equivalent in Ashland County, but bears the same relation to that outcrop as exists between the first two exposures mentioned. Our collections seem to indicate that *Pterinopecten ashlandensis* and *Athyris ashlandensis* have disappeared, while *Pterinopecten cariniferus* and *Lyriopecten nodocostatus* are very rare. *Spiriier marionensis*, *Mytilarca fibristriatus*, and *Poisidomya*

fragilis occur both here and in Licking County, while *Cyrtinia acutirostris*, which is found at Lodi, Medina County, rarely occurs here.

Coarse sandstone,	10 ft.	III2.
Conglomerate II,	5 ft.	
Sandstone,	12 ft.	II. 1

Four and one-half miles northwest of Wooster, the above section was obtained in a quarry. No fossils which could with certainty be referred to the strata farther south, were found here, but it is hardly possible that the conglomerate exposed can be conglomerate I, as the stratum below it is a solid freestone, containing *Chonetes*, while that below conglomerate I is usually a shale and no specimens belonging to the genus just referred to have ever been found immediately under conglomerate I. We should hardly expect conglomerate II to be so much thicker here than at Wooster; it must therefore be a local development, as it thins entirely out farther north. A few plants were found in it which is a new feature. The strata underlying the conglomerate show premonitory symptoms of the decline farther north

Freestone,	20 ft.	III.
Conglomerate I,	3 ft.	
Blue shale,	30 ft.	I5.

In this section which is exposed in Funk's Hollow, five miles northwest of Wooster, conglomerate II is not represented, the top of division II having been removed by erosion; in III *Syringotheris carteri*, *Sanguinolites aeolus ?*, and *Phaethonides occidentalis* were found. These in Licking County are confined to division two. Conglomerate I is underlaid by thirty feet of blue shale which is entirely unlike its equivalent farther south. The nodule layer is not exposed.

Sandstone and shales,	60 ft.	III2.
Conglomerate II,		
Losely bedded sandstone and shales,	15 ft.	II.

This section is revealed on the east and west banks of the Killbuck, eleven miles north of Wooster. The sixty feet of strata forming the top of the section, consist of alterating shales and beds of white sandstone, which are quarried in places. No fossils were found in this part of the section. Underlying this is about fifteen feet of sandstone and differs lithologically from its equivalent at Wooster. It contains poorly preserved casts of *Rynchonellae*. The position of

conglomerate II, which has thinned out, is approximately indicated by the presence of *Allorisma winchelli.*

White sandstone,	20 ft.	III2.
Blue shale,	35 ft.	III2.
Sandstone,		III2.
Sandstone,	30 ft.	III1.
Concretionary zone,	10 ft.	I4.

Ascending the Killbuck a short distance we find along Shade Creek, which empties into the Killbuck from the west the above section. About twenty feet of white sandstone containing *Schizodus newarkensis* ? and an undetermined species of *Orthis* forms the top of the section. The blue shale underlying it, is better exposed here than in the section last mentioned and contains numerous fucoids. The thirty feet of sandstone overlying the concretionary zone contains *Productus semireticulatus* (which only occurs in III and III2 in Central Ohio.) Whether these flags belong to III or III2, is doubtful, as no line can be drawn between them on any organic evidence. It seems probable, however, that the lower portion belongs to III, as fossils occupying that height occur farther north. The Waverly shale has thinned out at this locality. The concretionary zone is represented by *Syriopecten nodocostatus*, *Chonetes tumidas* and *Pterinopecten cariniferus.* About one mile from where Shade Creek empties into the Killbuck, and four and one-half miles south of Burbank, in a ditch by the road side, *Spirifer biplicatus* and *Productus duplicostatus* were found, both of these species occur in the middle part of division III in Licking County, as they are found on the same altitude as the upper part of the sandstone overlying the concretionary zone in Shade Creek, it would seem to indicate that the upper part belongs to that period. The lithological features are however entirely different from the flags at Shade Creek, and resemble the exposure at Burbank, Ohio. Two miles south of Burbank and a little below the last exposure, *Sanguinolites naiadiformis* and *Edmondia tapesiformis* were found. The former species occurs in III, in Licking County, while the second was described by Meek, from Richfield, Summit County, it has not been found in Central Ohio. On the Killbuck, a short distance southwest of Burbank, occurs the Cuyahoga shale of the Ohio geologists. This horizon would include the stratum last mentioned. At Burbank, *Spirifer biplicatus*, *Productus newberryi* and *Hemipronites cenistria* are the

characteristic species. At Lodi, Medina County, occurs thirty feet of argillaceous shale full of concretions, and in it are found four species which occur at Moots' Run, Licking County, viz: *Fenestella herrickana*, *Rhombopora ohioensis*, *Pterinopecten carinifera*, and *Terebratula ? inconstans*, while *Cyrtina acutirostris* which occurs in the nodule layer at Wooster is also collected here. This stratum is about 125 feet below the carboniferous conglomerate. It would thus seem that although the fauna at Lodi differs considerably from that of Moots' Run, the difference could be accounted for, by the gradual disappearance of species and new forms taking their place. We would correlate the Cuyahoga shale with its equivalents farther south in the same manner as the concretionary zone, as there is no reason to think that the Waverly strata, which were deposited subsequently, did not sustain the same relation to each other as when the concretionary stratum was deposited. The Cuyahoga shale, however, seems to have included elements above any of its equivalents in Central Ohio. For example, *Entolium aviculatum* and several species of *Aviculopecten*, which have affinities with coal measure forms. The different physical conditions under which the Cuyahoga shale was deposited necessarily brought in new forms, as *Allorisma cuyahoga*, *Entolium aviculatum*, *Solenomya cuyahogaensis*, and *Macrodon tennistriata*, and several other species which are not found farther south. It has also some species which occur in the Waverly of Central Ohio, viz: *Nucula houghtoni*, which has a range from thirty-five feet below conglomerate I to five feet above conglomerate II, *Spirifer biplicatus*, which is found in the middle part of division III, *Conularia newberryi*, which ranges from III_1 to III_2, and *Pleurotomaria stella*, which is found in III_1. These species will serve to illustrate the composite nature of the Waverly as represented in the Cuyahoga valley at and above the Big Falls.

It has been suggested in volume IV, page 103, of the Bulletin of Denison University, and in Vol. VI, page 37, of the Ohio Geological Survey, that the Cuyahoga shale as exposed in the valley of the Cuyahoga, should be separated on account of lithological and palaeontological differences existing between the different portions of the series as exposed in that locality. We will now describe the strata there, giving their equivalents as represented in Central Ohio as nearly as possible. It must be remembered, however, that the three subdivisions into which the series have been divided, blend into each other so that no line can be drawn separating them. Extending from the Big

Falls, 80 feet below the carboniferous conglomerate to that layer, we find a series of shales, &c., generally unfossiliferous, but containing two horizons, from which many species have been obtained. The first horizon, from which over thirty-five species have been figured in Bulletin Vol. IV, of Denison University, is forty feet below the carboniferous conglomerate, the second is exposed in the series of shales and freestones of which the stratum forming the Big Falls is the top. *Allorisma cuyahoga* and a species of *Chonetes* are the only species thus far obtained from that horizon. These zones are probably equivalent to divisions II and III of Licking County. We have seen that the Waverly shale, disappears at Shade Creek, north of Wooster, and consequently we should not expect to see it here. The concretionary zone (I4) has lost its lithological character here and has probably thinned out. Judging from the relative position it holds at Richfield its horizon would be under the Big Falls, More collecting will have to be done before anything definite can be said as to its position here. The Berea shale, which extends almost to the Big Falls, is very different, both lithologically and palaeontologically from the Cuyahoga shale proper. Five species have been obtained in this portion of the series, which are illustrated in Volume IV, Bulletin of Denison University, Plate X, Figs. 29, 30, 31, 32, 33. It will be seen by referring to that plate, that the portion above the falls has nothing in common with this shale, which is equivalent to a portion of division I3. The Berea grit and Bedford shale are respectively equivalent to I2 and I1 of Licking County.

2. TABULATED LIST OF FOSSILS KNOWN TO OCCUR IN THE WAVERLY OF OHIO.

Additions and corrections to the list published in Volume IV, page 123.

W. F. Cooper.

For the additions and corrections to the crinoids we are indebted to Mr. F. A. Bather, of the British Museum, London. The corrections adapt the list to the nomenclature of Wachmuth and Springer.

Crinoidea.

For Actinocrinus helice,	*read* Agaricocrinus helice.
" " viminalis,	" Amphoracrinus viminalis.
" Forbesiocrinius communis,	*read* Taxacrinus communis.
" " lobatus,	" " lobatus.
" " kellogi,	" " kelloggi.
" Poteriocrinus crineus,	" Scaphiocrinus crineus.
" " corycea,	" " corycea.
" " pleias,	" Decadocrinus pleais.
" Scaphiocrinus lyriope,	" " lyriope.
" " subtortuosus,	" " subtortuosus.
" Zeacrinus paternus,	" Woodocrinus paternus.
" " meriope,	" " meriope.
" Scaphiocrinus algini,	" Decadocrinus aegina.

Additions.

Taxacrinus lobatus, var. tardus.

Platycrinus bedfordensis, Hall and Whitfield, O. Pal. Vol. II, p. 161. Erie shale.

Platycrinus lodensis, Hall and Whitfield, Id. p. 168.

Woodocrinus richfieldensis, Worthen, Bull. I, Ill. State Mus. Nat. Hist. p. 15.

Agaricocrinus eris is a variety of A. helice.

Lamellibranchiata.

Cypricardinia consimilis, Hall.
Edmondia ellipsis, Hall.
Elymella patula, Hall.
Macrodon ovatus, Hall.
Nuculana pandoriformis, Stevens.
Palæaneilo truncata, Hall.
Pararca erecta, Hall.
Pterinopecten shumardanus. Pernopecten shumardanus.
Schizodus (chemungensis var.) prolongatus. Hall.
" aequalis, Hall.
Sphenotus æolus, Hall.
" flavius, Hall.
" valvulus, Hall.
" signatus, Hall.

Brachiopoda.

Syringothyris typa, Win.
Lingula cuyahogensis, Hall.
" subspatulata, M. and W.
Productus cooperensis, Swallow.
Strophomena rhomboidalis, Wilchins.

Crustacea.

Paoetus haldemani ? Herrick.

Gasteropoda.

Flemingia ? stulta, Herrick.
Pleurotomaria strigillata, Herrick.

3. THE CENTRAL NERVOUS SYSTEM OF RODENTS.

(Preliminary Paper)

[Read by abstract before the Denison Scientific Association, April 5th, 1890.]

C. L. Herrick and W. G. Tight.

Tho following notes upon the central nervous system of *Arctomys* are intended simply as an introduction to the more detailed work which it is hoped to devote to the nervous anatomy of the rodents. While much has already been done in the examination of other types and some effort has been made to homologize the structures described with those of other orders of mammals, only a few disconnected references to such results of our work can be well introduced. The publication of an incomplete installment of the paper seems advisable, because of the large number of figures which will be necessary to fully carry out the undertaking. These drawings being faithful photographic copies of sketches made by the aid of the camera lucida, are relied upon to give our notes a certain value even in their incomplete and imperfect state.

The several paragraphs having been written by different hands and often without opportunity for consultation, it is obvious that disparity in style and diversity in treatment may be expected. The responsibility is, therefore, a mixed one, and it will not be possible or necessary to unravel it entirely; the drawings, however, are accredited to the authors respectively, and from the references to these the source of most of the statements may be gathered.

In the present conflicting condition of neurological literature the smallest contribution of exact data upon the minute structure of the brain should be welcome, and the most hopeful field for the solution

of the perplexing problem lies in work upon the simpler types. The subject chosen possesses several advantages. It is a primitive representative of the sciuromorphs or squirrel-like rodents, having simply organized cerebrum and yet a greater exposed cortex than the myomorphs which, at first thought, might have been preferred. The brain is large enough for localization experiments, but small enough for continuous sections through at least one-half of the brain. Another incidental advantage is that the type is one whose cerebral anatomy has not been exhaustively treated. The resemblance in many respects is close to the brain of the hare, and we have data derived from the latter subject sufficient to serve as a guide in the present case. During the progress of the work the desirability of comparison with the brains of even lower types of structure became so obvious that resort was taken to the alligator and Amphibia, the results of a brief study of the former being embodied in a paper by one of us, in the current volume of the Journal of the Cincinnati Society of Natural History. A similar study of the brain of the opossum, being now in progress, may be shortly expected.

Inasmuch, however, as the work upon the ground hog has been so long under way and some of the results have already been published, it has been thought best to present it as it now stands as introductory to the more detailed anatomy of other rodent types.

A word regarding the method followed may be appropriate:

The subject chosen was the ground hog, *Arctomys monax*, while the brains of rabbits, opossums, and raccoons served for comparison. The functions of the cortex were investigated by electrical stimulation and extirpation. In this way the motor centers for the fore and hind legs, the muscles of the face and neck, and the sensory areas were accurately diagramed. A method used by us for the first time may be incidentally mentioned as worthy of more careful employment. As the electrodes were removed from the brain a small pasteboard or wooden peg bearing a number, was inserted and the reaction produced at this point was carefully recorded upon a diagram of the surface of the hemisphere with the corresponding number attached. After the removal of the brain these tags served to check the accuracy of the diagram, and a careful drawing was made including the areas experimented on.

The brains were placed in chromic solution twenty-four hours and then in alcohol, and continuous series of sections taken in various direc-

tions mounted in balsam. Several hundred such sections were prepared and studied by the method of geometric reconstruction from camera drawings and measurements.

The chrom-acetic solution appears to us to have decided advantages over any other fluid used. For some brains it should be considerably more dilute than the standard advised by Fol. The most generally satisfactory stain is aqueous haematoxylin with the possible exception of a new stain, an account of which is at present reserved. Alum-cochineal ranks next and, although it does not preserve the fine histological details and causes a shrinking of cells and delicate organs generally, it has the great advantage of being adapted for the staining of fragments in toto, thus enabling one to fix the sections upon the slide at once, obviating the danger of loss as well as avoiding the great labor involved in the usual hæmatoxylin method. The ordinary carmine stains are relatively useless as are the alcohol solutions of hæmatoxylin, etc.

Analine blue-black has many of the good properties of hæmatoxylin but seems less desirable on the whole. A solution of methyl blue in oil of cloves promised well, but it was found impracticable in actual practice. So far as our experiments went the mingling of stains with Mueller's fluid proved unsatisfactory.

In some cases alum-cochineal serves to differentiate the fibre tracts very perfectly, but those preparations are less perfect respecting the cells. In fact no reagent was found serving both purposes equally. We have preferred, therefore, the use of a reagent which alters the natural relations as little as possible and permits the tracing of what may be confidently regarded as the normal connections albeit at great expense of patience and time. Successfully stained hæmatoxylin preparations do this. The various methods of staining fibres only, although undoubtedly of the highest value, do not prove adapted for the minuter work of tracing cells in their mutual relations. Ours has been the common fate. It has not infrequently happened that the same process applied to two entirely similar brains has resulted in failure in one case and success in another. Thus far no infallible technique has been discovered. The statements made on the basis of the few specimens studied must remain open to the criticism of subsequent study.

Previous to the sectioning, as already said, several localization experiments were made both by electrical stimulation and extirpation. The first specimen was a male of *Arctomys monax*, the same specimen which

furnished the sections most frequently described and figured beyond. Ether was employed as an anesthetic, and the skin was parted down the median line of the head and the skull removed over the anterior and middle parts of the left hemisphere. The current used was from one Grove cell and was just enough to operate the induction-coil, producing an irritation easily endured by the tongue When the electrodes were introduced at *a*, *Fig.* 4, Plate V, (at about the anterior one-third, near the median line and corresponding approximately to Munk's region C of the dog) a forward and outward motion of the right fore leg was produced. A stronger current produced an electrotonic contraction of the muscles of the whole right side. At the point *b*, about 5 mm. behind and a little outward from the above (corresponding to about the posterior margin of Munk's region D), the stimulus produced a straightening of the right hind leg. At the point *c*, about 8 mm. behind *b*, and near the median fissure (corresponding to about Munk's region F, near the median line), the stimulation resulted in a sharp contraction of the orbicularis palpebrarum and orbicularis oris of the right side and some feeble contraction of the facial muscles of the left side, probably due to superficial irradiation.

At the point *d*, about 8 mm. behind *c*, and farther from the median fissure, (corresponding to the anterior margin of Munk's region A,) the insertion of the electrodes produces no motor disturbances nor did any point back of *d*. By a series of trials it was found that the electrodes produced some motor disturbance of the fore leg at all points within the area marked A, but not beyond it.

The area B likewise marks about the limits of the hind leg region. An area of about 5 sq. mm. was then removed from the cortex of the left side in the fore leg region at about *a*. The wound was then dressed and the animal allowed to recover. The power of abduction of the right fore leg was lost. After some time another portion of the cortex was removed, a little back of *d*, on the left side. After recovery it was found that the animal was blind in the right eye. These experiments serve to locate some of the motor and sensory regions of the cerebral cortex for the subsequent histological works.

It may be of interest to note also one of the series of experiments of electrical stimulation upon the Raccoon, *Procyon lotor*, which has been employed for comparative study. The animal was a male about three-fourths grown. Just enough current was used to drive the coil. Ether and chloroform mixed were the anesthetics employed.

Nearly the whole upper surface of the cerebral hemisphere of the left side was exposed. The loss of blood was very moderate.

The electrodes were introduced at point 1, *Fig.* 2, Plate XI, about 9 mm. from the median fissure and a little in advance of the line passing through the anterior angle of the eye. The result was a forward and inward motion of the right fore leg.

At point 2, the introduction of the electrode gave an undefined movement of right fore leg.

At point 3, about 7 mm. from the median line and separated from 1 by a faint sulcus, the stimulation produced a flexion of the pes on the crus and elevation of right hind leg.

At 4, a movement of the right hind leg, as at 3, and a slight rotation of the fore leg inwards.

At 5, about 3 mm. from the median line, the stimulation produced an extension and divarication of the digits of the right foot.

At 6, the fore leg was elevated and flexed, and with a little stronger current the hind leg was also elevated and flexed.

At 7, there was an extension of the toes corresponding to the movements produced at 5, of the opposite side.

Perhaps more important in its bearing on the present subject is a set of experiments upon the opossum, of which, unfortunately, no very exact data have been preserved. The configuration of the hemispheres as well as the details of structure resemble very closely those of rodents. Moreover, such hints as we have of the development of the Rodentia indicate a common origin for the two groups and comparatively slight subsequent differentiation. It, then, would not be surprising if a considerable similarity of distribution in the cortical elements should be proven to exist. On the other hand, the existence of an apparent homologue of the crucial sulcus near the front of the cerebrum would lead one to expect the aggregation of the motor elements near this sulcus. The experiments in this case were made with a Grenet cell and DuBois-Raymond coil, with the secondary coil at about 8 cm. the current being applied by a pair of platinum electrodes separated by about 3 mm. Stimulation of the region about the crucial sulcus (so called) resulted in movements of the anterior extremity, but the difficulty in controlling the flow of blood interferred with close analysis. The area on either side of the median fissure responded with various poorly localized contractions of the trunk. About 6-8 mm. posterior to the crucial sulcus and 4-5 mm. from the medial line is an ill-defined

area governing the hind leg. These motor reactions were, in the main, crossed as usual, but in several instances similar motions of the muscles of both sides resulted when superficial irradiation appeared to be excluded. The areas thus roughly mapped in the opossum coincide in general with those of the ground hog and we are forced to conclude that the crucial sulcus of the opossum is not strictly homologous with the fissure so named in carnivora.

The rodent brain is especially noteworthy because of the reptilian simplicity of structure. The smooth, depressed and elongate hemispheres, protruding and exposed olfactory lobes, and partially exposed optic lobes are such characters. The large, highly convoluted cerebellum redeems the mammalian habitus of the brain. The convolutions have definite patterns which may be of generic or possibly ordinal character. The extended flocculus is a rodent character. The forward extension of the chiasm and the great obliquity of the optic tracts, as well as the distinctness of the thalamus from the axial portion of the hemisphere may be regarded as primitive or degraded conditions as are the relatively posterior position of the corpus callosum, the distinctness of the fornix and its relation to the hippocampus and the great size of the ventricles. In spite of the considerable size of the cerebellum, it does not entirely cover the fourth ventricle. The several spinal nerves have a degree of independence greatly facilitating their study.

The comparison with the opossum on the one hand and Carnivora on the other is instructive as illustrating the range of variation in structures essentially similar. The most marked difference between the rodents and marsupials consists in the relative importance of the two great commissural systems of the fore-brain.

In *Didelphys* the callosum is practically absent and the fibres serving the function of the corpus callosum in higher mammals are associated with the anterior commissure. The structure of this region in the opossum is of great interest. The great mass of transverse fibres constituting the commissural system of the fore-brain consists of four elements, viz :

1st. Fibres from the olfactory tract which cross from the pyriform lobe to the thalamus near the brain base and ascend to the level of the lower surface of the anterior commissure, where they turn abruptly cephalad and decussate as they mingle with that commissure. 2d, the fibres of the anterior commissure itself, which, as already suggested,

gathers fibres from the cephalad as well as occipital regions at least of the ventral portions of the hemispheres. 3d, the commissure of the hippocampus is quite distinct from the previously mentioned, and is quite a narrow and slender band of considerable length, as the hippocampi, posteriorly, are oval or quadrate in section and at the point of origin of the fornix or hippocampal commissure are widely separate. 4th. A rudiment of what may be called corpus callosum, although we are unwilling to homologize it definitely with that body. The last mentioned is a small fibre-tract which lies anterior to but adherent upon the hippocampal commissure and soon loses itself in the median walls of the hemispheres corresponding to the septum pellucidum. Being a tract of the cortex this band has as great claim to be homologized with the corpus callosum as the relatively larger commissure of the alligator.

Exactly the same relations between the hippocampal commissure and the callosum are found in the insectivora, as may be seen by comparing Plate X, *Fig.* 7, except that the latter possesses a well-defined corpus callosum above the ammon's horn.

Comparing with these a section through a corresponding region of the kitten (Plate XII, *Fig.* 6), the relations appear very different, but the difference arises chiefly from the different proportions and the relative compactness of the brain whereby the thalmus and corpora striata are crowded upon each other. The wide interval between the anterior commissure and the callosum may be regarded as an incident of this consolidation. Finally, the examination of Plate X, *Fig.* 5, reveals the fact that the hippocampus has a very similar relation in the rabbit. This section, although nearly horizontal, inclines toward the median line from the cortex of the right hemisphere and embraces a segment from the middle region simply.

Before passing to a description of our own investigations, it may be well to present a summary of the results of Stieda's work upon the rabbit and rat. This summary will serve as an introduction to the subsequent paper as well.

After removing the tuber cinereum, which is but a small protuberant portion of the thalamus below, the latter appears divided by the thin cleft representing the third ventricle into two symmetrical halves. The ventricle is divided into a lower and upper portion by the adhesion of the walls, often called *commissura mollis*, which, however, is not a true commissure. The ventricle descends to the tuber cinereum.

In front of the corpora quadrigemina is a strong *posterior commissure*. The lower portion of the third ventricle pertaining to the tuber cinerum is bounded behind by the tuberculum mamillare and the substantia cinerea posteriora, in front by the thin grey lamella rising to the corpus striatum, the *lamina terminalis*.

The *copora striata* are pear shaped bodies, the anterior portions of which are connected by the *septum pellucidum*, which, in turn, is connected with the lamina terminalis. The septum is perforated by the fibres of the *commissure anterior*. The lower surface of each hemisphere is provided with a protuberance or *processus pyriformis* (in reality produced by the fold of the hippocampus) which is separated by a sulcus (*rhinalis* and *post-rhinalis*) from the remainder of the cortex. From the anterior or narrow portion of this pear shaped area extends the olfactory lobe.

Removal of successive horizontal slices of the hemispheres exposes the *callosum*, which is medianly connected by a considerable adhesion with the *cornua ammonis*. Each lateral ventricle is a cavity lying between the corpus striatum and septum pellucidum in front and between the corpus striatum and cornu ammonis below and medianly. After suitable preparation, fibres can be seen crossing below the callosum and ending in the groove between the thalamus and striatum and probably representing the posterior limb of the fornix.

Cranial Nerves I and II, as usual. The *oculomotor* (III) springs from the median surface of the crura, just behind the corpus mamillare. The *trochlearis* (IV) originates as a fine fibre from the horizontal part of the valvula cerebelli, immediately behind the quadrigemina. The *trigeminus* (V) arises just posterior to the pons and is composed of a lateral portio major and median portio minor. The *abducens* (VI) emerges near the median line, near the posterior margin of the pons. The *facial* (VII) emerges obliquely from the medulla behind the pons upon the corpus trapezoideum. The *auditory* (VIII) springs from the lateral surface of the tuberculum laterale, immediately behind the *trigeminus*. The *glossopharyngeal* (IX) is a root of about three bundles springing from the lateral surface of the medulla behind the tuberculum laterale, forming a small ganglion. The *vagus* (X) consists of several bundles, forming an arch along the lateral surface of the medulla, the lowest bundle being continuous with the *accessory* (XI), fibres of which extend back as far as the third or fourth spinal nerves. The

hypoglossus (XII) springs, with a rather large number of fibres from the lateral margin of the pyramids.

The increase in the size of the *medulla* from behind forward is accompanied by an increase in the amount of gray matter, and also an inter-reticulation of the gray and white matter. This reticulation is the forward extension of the *formatio reticularis* of the cord. The posterior cornua are divaricated cephalad, and between them are interpolated accessory gray masses, the *corpus cuneato gracile*. The posterior part of the dorsal cornu increases in size, forming the *tuberculum Rolandii*. In the anterior (ventral) cornua the lateral giant cells disappear, but in the gray matter of the reticulum are very numerous medium and small cells. Only in the higher (cephalad) regions of the medulla do large multipolar cells (.08 mm) reappear.

In the caudal part of the medulla, near the pyramidal decussation, appear two groups of cells, the *basal* and *lateral nuclei*. The first is rather broader than the pyramids, dorsal to which it lies, and extends upward (cephalad) to about the middle of the medulla. The cells measure .016–.02 mm., with nuclei .008– 01 mm. in diameter, and have only obscure processes. This nucleus is divided into subordinate cell clusters by numerous fibres passing in all directions, which evidently have their origin here. The lateral portions of this nucleus are regularly perforated by the roots of the hypoglossus. The second group (nucleus lateralis), lies in the antero-lateral (ventro-lateral) portion of the medulla, extending a shorter distance cephalad. The cells are multipolar with angular outlines and are of median size and not closely packed. Another cell cluster, *nuclus centralis*, lies on either side of the ventricle and its cells are spindle shaped and longitudinally placed, measuring .024 mm. An additional cluster (hypoglossus nucleus), extending a shorter distance caudad and lying ventral to the above, consists of multipolar cells .04 mm long, and retains its position near the ventricle, while the dorsal portion extends laterally toward the front. A cell clustre in the *corpus cuneato-gracile* may receive the same name and anteriorly *nucleus restiforme*. Cephalad in the medulla, after the termination of the basal nucleus, angular cells, .04 mm. in diameter collect on either side of the raphe forming the *nucleus* of the *raphe*. Cephalad from the nucleus lateralis, and distinctly separated from it, is the nucleus of the facialis, the cells of which are multipolar, with processes ascending to the root, and measure about .04 mm.

The dorsal and lateral longitudinal bundles are indistinct, but a

ventral bundle lies ventrad from the median nucleus and is bounded laterally by the hypoglossal fibres. Along the anterior surface the pyramids are very obvious. Numerous concentric fibres crossing in the raphe are also mentioned. The *fibrae arciformes* which consist of oblique fibres springing from the lateral aspect of the pyramids, curve dorsally and cephalad to the corpus restiforme, collecting there to a considerable bundle, passing cephalad, and disappearing under the tuberculum laterale.

The *hypoglossus* has two sorts of roots, some resembling in origin the roots of the anterior spinal nerves, and a bundle which springs from the nucleus above described near the sides of the fourth ventricle. There is no doubt that the nerve receives crossed fibres from the opposite side and from the longitudinal bundle.

The *accessory*. The caudal roots, *i. e.* those in the region of spinal nerves, turn abruptly to enter longitudinal bundles lying in the gray and probably arising from the anterior (ventral) cornua. The roots of the cephalad division of the accessory with those of the *glossopharyngeal* and *vagus* enter the tuberculum Rollandii, pass toward the median nuclei, but suddenly turn to form longitudinal bundles not traceable to definite nuclei. The fibres from the ventrally situated *facialis* nuclei converge dorsally, forming a considerable longitudinal bundle on either side the canalis centralis, and, turning laterally, pass, without crossing, to their exit through the longitudinal fibres of the trapezoideum.

The nucleus of the *abducens* lies lateral to the knee of the facial root, *i. e.* in its concavity. The cells of the abducens are of the same size and appearance as those of the facialis. The fibres pass ventrally and then laterally without crossing. The *acusticus* consists of the two roots, the dorsal root sends fibres to the tuberculum laterale, but a part pass beyond to the gray matter of the wall of the ventricle, where they possibly terminate in small cells. The ventral root-fibres form numerous small bundles which, after perforating the lower part of the tuberlum laterale, diverge in several directions. A small part turn abruptly dorsally to unite with the dorsal root, the remainder follow the longitudinal course of the fibræ arciformes to a position within the crus cerebelli, where there appears a large nucleus composed of large multipolar cells and which may be regarded as the nucleus of the acusticus.

The *trigeminus* has two roots, the larger of which is composed of

small fibres, the immediate derivitives from a longitudinal bundle appearing far caudad in the medulla and anteriorly covered by the longitudinal bundle of the fibræ arciformes. A smaller longitudinal bundle lies in the tuberculum Rolandii. The smaller root springs from a nucleus of large multipolar cells, like those of the facialis, lying below the floor of the ventricle. Its fibres curve dorsally, then ventrally and laterally to their exit. A part, however, of the trigeminus fibres can be traced to the nucleus of the trochlearis. The cells of the *trochlearis* nucleus are rounded and have few processes. The nucleus is elongate, and its fibres pass dorsally and caudad to the decussation in the valvula cerebelli.

The Cerebellum. The medulla is connected with the cerebellum by the fibræ arciformes, there being no connection via corpora restiform. The entire mass of the crura cerebelli ad corpora quadrigemina is derived from the cerebellum.

In the *pars peduncularis* the pyramids appear quite lateral, while the anterior longitudinal fasciculi occupy a place between them and are only separated from each other by the substantia cinerea posteriora media. In addition there is a dorsal fascicle, and isolated fibres from the cerebellum.

The gray substance between the longitudinal bundles is composed of a granular basis with small round or spindle cells and contains the following nuclei. The nucleus peduncularis consists of a lower portion composed of numerous small cells (.012–.016 mm.) and an upper smaller nucleus, with large multipolar cells (.04 mm). This nucleus occupies a lateral, ventral position below the nucleus of the *oculomotor*, which its upper portion resembles.

The corpora quadrigemina, thalami and optic region were not fully studied.

The *corpora striata* consist of mingled gray and white matter, the side nearest the ventricle being almost altogether gray, and the lateral portion united with the hemispheres is full of fibre bundles. The gray substance contains small round or fusiform cells with exceedingly fine processes and measuring .008–.012 mm.

The hemispheres are evidently zonary, the outer layer having a thickness of 0.5 mm., followed by a gray layer reposing in turn upon the inner white. The gray matter of the cortex consists of three layers of cells: first, an outer layer of small cells .008–.016 mm. long, and closely aggregated; second, the layer of large cells .04 mm. long,

which are triangular with a single peripheral process; third, small cells differing from the outer or first layer in that the cells are more spherical, while the cells of the outer layer are spindle shaped.

On the ventral surface of the callosum the cornua ammonis are connected by transverse fibres. The gray matter of the lower, or pyriform lobe fuses directly with that of the striatum, and its superficial cell-layer is composed of cells like that of the peripheral, and these are closely compacted and arranged in a tortuous line.

The septum pellucidum conforms in structure to that of the cortex. The anterior commissure consists of fibres, a part of which radiate to the striatum, and a larger part to the olfactory lobes.

The pyriform lobe, or protuberance of the ventral surface of the hemispheres, lacks the inner white, its outer cellular portion fusing directly with that of the corpus striatum.

The general description above condensed is in nearly every detail applicable to the ground hog so that it will render unnecessary any discussion of the external features Sundry discrepancies and errors in the histological descriptions may be noted by comparison with the following pages.

A detailed special account of the gross anatomy of Arctomys monax, by one of us, is incorporated beyond; for the present a brief review of current views upon the questions here chiefly discussed may prove a fitting introduction to the descriptions.

With reference to the cortex the prevailing attitude is one of agnosticism, as may be inferred from the following passage frome Raue:

"If the latest researches of Max Schultze are correct, it appears that the nerve cell is essentially only an enlargement, with nucleus and nucleolus, of the axis-cylinder; that, therefore, it does not represent the beginning. but is merely an intervening expansion of the nerve in its course. The bipolar cell is so to be considered. In the case of the multipolar cells of the spinal narrow, from which, according to Deiter's discovery, one axis-cylinder issues to pass toward the periphery, while many other processes spread in different directions, the cell appears to be an intermediate station for the conveyance of innumerable nerve fibrils from different regions in order to unite and form one axis-cylinder. Even here the axis cylinder cannot be considered as *originating* within the nerve cell. It is only made up there, like the bulk of a main stream, from numerous tributaries, the source of which no one has yet discovered. The researches of Deiter also made it prob-

able that the groups of ganglion cells, from which the cranial nerves arise, and which have been made known by Stilling as the nuclei of sensory roots, consist of cells in form entirely similar to those from the anterior and posterior cornua of the spinal marrow, and that they, like these, send off only one axis cylinder, which passes toward the periphery, while the other processes divide into innumerable primitive fibrils."*

Turning to the morphological aspects of the same problem, the results are similar. Thus in the literature before 1870, although all agreed that the cortex is laminated, Baillarger (1840), Gerlach (1852), Berlin (1859), and others, described six layers, Koelliker, four to six, Arndt, five to six, and Meynert, nine. The giant pyramids or "pyramidal bodies," (Meynert), were described by Arndt as pyramids with five or more fine branches from the base, which divide dichotomously and are lost in a nervous reticulum of the ground substance, while the apex process passes upward, then abruptly turns downward to form an axis cylinder. Meynert, and after him Loechner, Kollman and Stieda, on the contrary, claim that the apical process divides, while, besides the baso-lateral processes there is a median basal double-contoured fibre which passes into an axis cylinder.

Meynert say, (Psychiatry, p. 70): "Betz has stated that the anterior central convolution contained groups of particularly large pyramids, which he thought were the circumscribed motor centres which Hitzig, on the strength of his physiological experiments, relegated exclusively to the anterior central convolution of the brain of dogs and monkeys. Apart from the mistake which Hitzig made in establishing the homologue in carnivora of the anterior central convolution, it has been proved that the size of the pyramids depends upon their distance from the cortical surface. The largest pyramids will, therefore, be found in the broadest cortical region; but the broadest cortical region is that of both central convolutions. * * * The largest pyramids appear to be arranged in small groups at some distance from one another. It would be wrong to argue from this that these large pyramids have a different signification from the smaller ones. Luys is in a great measure responsible for this mistake. Betz appears to me not to have

[* *Raue*, Psychology as a Natural Science applied to the Solution of Occult Psychic Phenomena, 1889.]

made a discovery, but to have failed to appreciate the relations which obtain in the primary disposition of the cortical elements."

The study of the cortex in animals which, like rodents, have an unconvoluted cerebrum, proves that Betz was entirely right in associating special motor areas with enlarged pyramids, as we hope to sufficiently show. The real basis for subsequent work is indicated by the following passage from Meynert:

"No morbid change and no physiological experiment gives us any reason to hope that we shall be able to explain the difference in form of cortical elements in closely neighboring layers. Morphological interpretation is the only method which can come to our rescue The nerve corpuscles of the gray anterior horns of the spinal cord, of the central nuclei of the hypoglossal, facial and abducens nerves, and as far upwards as the oculomotor nerve, all show long, slender cell forms with numerous processes. These processes seem to arise with a broad base from the body of the cell. The same peculiarities of configuration which we observe in those nerve cells, which are connected with the centrifugal nerve tracts, are found in the cortical pyramids, and there can only be explained by the similarity in the distribution of those bodies. Gerlach has compared the median base process with those spinal cell processes which enter the anterior roots. The granules of the fourth cortical layer, which are distinguished from the free nuclei by their size and protoplasm, from the spider and spindle shaped cells by the distinct boundary of their protoplasm, and by a lesser number of stout processes, may be likened to those branched ganglionic cells which occur in centres connected with centripetally conducting tracts.'—(*Meynert*, Psychiatry, p. 66.)

The paper of Golgi (Revista sperimentale, 1883), has remained inaccessible to us but, judging from excerpts, Koelliker's criticism (Anat. Anzeiger, 1888, II, No. 15,) seems justified. Especially we feel constrained to call attention to Koelliker's suggestion that the outer zone contains fibre tracts of major importance. This we had previously determined and in the case of lower vertebrates the existence of prominent tracts in the so called neuroglia layer is well demonstrated.

Koelliker says: "Sehr eigentuemlich ist, was Golgi ueber die axencylinderfortsaetze die nervenzellen mittheilt. Dieselben sollen in zwei Formen vonkommen. Bei den centrifugal-wirkenden (motorischen) Zellen soll der Fortsatz im ganzen mit gleichbleibenden Staerke zum axencylinder einem dunkelrandigen Fasser werden, auserdem

arber auch eine gewisse Zahl fieiner sich veraestelnder Fortsaetze in eim nervoeses Netz abgeben, dass nach Golgi Nervenfasern und Nervenzellen verbindet. In dieses Nets treten auszer den eben genannten feiner Auslaeufern, noch ein (1) feine veraestelte Auslaeufer der motorischen Nervenfaesern, welche von den Axencylinderfortsaetzen der motorischen Zellen entspringen, (2) Fortsaetze der centripetal erragbaren (sensiblen) Nervengellen, die Golgi als nervoese bezeichnet, arber in ein feines Netz sich aufloesen laeszt, (3) endlich veraestelte feine Auslaeufer der centripetal wirkenden (sensiblen) dunkel-randigen Fasern. Mir will es nun, trotz aller Anerkennung der wichtigen errungenschaften Golgi's, vorkommen, als ob die existenz eines solchen verwikelten nervoesen Netzes nicht hinreichend sicher begruendet sei "

The question as to the anastamoses between different ganglion cells has been laboriously argued. Some few, like Claus, Viallanes, Wagner and, more recently, Nansen have denied the existence of such connections. Nansen says:

"I have on several occasions firmly denied a common existence of direct combinations between cells, not having found any case of indubitable anastomosis between cell processes." "The 'neuroglia cells' and fibres, which are interposed between the ganglion cells, have certainly assisted a great many writers to see anastomoses, as they have not understood the real nature of this supporting tissue."

The author admits what we have very frequently seen beyond doubt, that lateral communication certainly exists as a result of cell division, but seems to believe that there is a subsequent solution of continuity. He says:*

"When one has examined so many preparations (stained by the most perfect methods) as I have, without finding one anastomosis of indubitable nature, I think one must be entitled to say, that direct anastomosis between the processes of the ganglion cells does not exist, as a rule. What previous writers have supposed to be anastomoses is, in my opinion, probably the neuroglia reticulation generally extending between ganglion cells. * * * Another objection against a direct combination, and which does not seem to have been thought of by a great many authors, is the existence of unipolar cells."

[*The structure and combination of the Histological Elements of the Central Nervous System, p. 8 6.]

Nansen agrees with Golgi in identifying two kinds of processes, nervous and protoplasmic. "Of nervous processes each cell (unipolar or multipolar) has always one and never more; the nervous processes are always directed toward the dotted substance, or in a few cases pass directly into the peripheral nerves."

The results of such a condition as this are evidently realized as revolutionary, as reference is made to the observations of Fritsch.*

"Die apolare ganglion-cellen haben lange genug in unserer Literatur gespukt." "Eine wirklich unipolare Zelle ist fuer den Organismus nicht viel mehr werth als eine apolare Zelle." To this the present writers fully assent and furthermore find abundant evidence of the existence of two fully developed "nervous processes" in very many cells connected with the cranial nerves as well as in the cortex and feel that the ganglion cells might as well be dismissed from the ranks of servitors of cerebral function if deprived of all members but one. How the function of inhibition, for example, can construe with such a condition, does not appear.

Nansen proceeds: "When a ganglion-cell is bipolar, then the processes it possesses, besides the nervous process, are protoplasmic processes. These protoplasmic processes are not directed toward the dotted substance, but generally have a peripheral direction toward the external layers of the central nervous system." "Like Prof. Golgi, I believe the function of the protoplasmic processes to be a nutritive one; when the ganglion cells can not get sufficient nourishment in their neighborhood, they have to send processes toward the periphery of the nervous system." "Having elucidated that no combination between cells can be produced by the protoplasmic process, and as it is very improbable that any combination between them can be produced by the neuroglia, I suppose it to be most probable, if not certain, that if any combination upon the whole exists between the ganglion cells, then this combination must be produced by the nervous processes. That such a combination can exist, with the dotted substance as a medium, we can readily understand when we think of the course of the nervous processes. There may be drawn a distinction between *two types of ganglion cells* in respect to the course of their nervous processes; viz: (1) ganglion cells with nervous processes which directly become nerve tubes and thus do not lose their individuality

[*Arch. mikr. Anat., 1886.]

though they have no isolated course, *but give off side-branches* to the dotted substance ; (2) ganglion cells with nervous processes which lose their individuality and by subdivisions are *entirely broken up into slender branches,* losing themselves in the dotted substance."

To sum up all, the logical result of Nansen's observations could not long be evaded, and he boldly announces the belief that all ganglion cells are merely nutritive, or may possibly be also seats of memory apparently regarding those functions as closely allied! All really nervous functions proper, on the other hand are referred to the "intricate web or plaiting of nerve-tubes and fibrillæ in the dotted substance." Perhaps this is the result to be expected from two implicit reliance upon the method of metallic impregnation.

Without spending more time in the discussion of these theoretical considerations we may now pass to the study of our sections, and in the present paper confine ourselves to the description of observed structures, reserving their discussion for a subsequent occasion. If, therefore, what follows resembles too closely a bare description of plates, we trust it may serve to prepare for subsequent comparisons.

External form and measurements.

That portion of the brain in front of the bridge is ob-pyriform, the olfactory lobes corresponding to the stalks of the pear. These lobes protrude 9-10 mm. beyond the hemispheres and are attached to their crura by an oblique plane looking dorsad and caudad as well as laterad. The crura are about 5 mm. wide at the attachment and widen caudad to become continuous with the pyriform lobes and, from hemispherical prominences, sink to slight elevations whose surface is excavated by vessels from the circle of Willis, which cross transversely about 13 mm. from the front. Immediately caudad to this depression the pyriform lobe springs ventrad as a strong protuberance. A well defined white band on the ventro-lateral exposure of the crural expansion indicates the position of one of the external olfactory tracts, which passes parallel to the rhinalis fissure and plunges into the pyriform lobe near the middle of its cephalad portion. A smaller band lies nearer the median line. The greatest ventral projection of the pyriform lobe is opposite the infundibulum and it is the posterior free margin of the lobe which constitutes the hippocampus, to the inversion of which the protuberance is due. The chiasm lies about 10 mm. back of the anterior margin of the hemispheres and there seems to be a small band of the

chiasm system which is partly distinct, lying partly imbedded in the tuber cinereum and crossing directly. Back of the tuber is a well marked trigonum inter-pedunculare, but the third nerves arise from the strongly divergent peduncles near their median margins.

The medulla is coffin-shaped in outline, its sides consisting of a short anterior oblique, a median longitudinal, and a longer posterior oblique portion. The third nerve is relatively large as compared with the opossum, being ten times the size of the fourth nerve, and arises from a number of closely united roots.

The fourth nerve is very small and springs from the very lateral portion of the valve of Vieussen's, thence passing to Gasser's ganglion.

The fifth has two distinct roots, the ventral portion being a broad, flat band extending nearly horizontally from the base of the main root, from which it is elsewhere independent until merged in the ganglion of Gasser.

The main root is ten times as large and is flattened slightly horizontally.

The sixth nerve consists of three nearly equal roots springing obliquely from the posterior margin of the pons and along the lateral margin of the ventral median tract of the medulla, which here is very distinct.

The seventh nerve lies in the same antero-posterior plane as the sixth and 1 mm. caudad to the fifth. It is a rather large, flat band passing directly lateral, its fibres entering the medulla nearly parallel to the surface.

The eighth is partly covered by the seventh when viewed from below, and separates imperfectly at first into its two branches. Its tract passes superficially dorsad under the cerebellum to a prominent eminencia acustica. The ninth and tenth nerves immediately follow, but differ in direction. The eleventh can be traced to at least the third cervical. The twelfth arises by three clusters, increasing in size backward and springing from the margin of the medio-ventral tract.

As compared with the opossum, the brain is broad and compact, the olfactory lobes are relatively small, the optic chiasm is larger, the pyriform lobes are more distinct and prominent, the rhinalis fissure more distinct, and the pons is much larger, as are the cranial nerves. As compared with the rabbit the brain is more massive and compact, but otherwise exhibits only minor differences.

The following measurements are added:

Total length, 5 cm.; length of olfactory lobes, 12 mm.; front of hemisphere to chiasm, 12 mm.; to posterior third nerve root, 24 mm.; to bridge, 26 mm.; to posterior of pons, 33 mm Total width of cerebrum at base, 32 mm; at chiasm, 26 mm.; distance between opposite sulci rhinales at chiasm, 21 mm.; space between opposite pyriform lobes at nearest point, 8 mm; distance between fifth nerve roots, 10 mm.; distance between seventh nerve roots, 11 mm.; distance between sixth nerve roots, 5 mm.; distance between eighth nerve roots, 12½ mm.; width of cerebellum at widest part, 25 mm.; width of cord at base of medulla, 8 mm; width of medulla near lower end, 13 mm.; from anterior of bridge to first spinal nerve, 21 mm.; from anterior of bridge to second spinal nerve. 25 mm.; from anterior of bridge to third spinal nerve, 30 mm.; median length of hemispheres, 47 mm.; width of cerebellum exclusive of vermiform, 22 mm.

Structure of the cord and medulla.

The cross sections of the cervical region of the cord of *Arctomys* show the relations of the white and gray matter to be rather primitive. The minor subdivision of some of the longitudinal columns can not be determined so readily as in higher types.

The central gray matter divides the cord into the ventral, lateral, and dorsal columns. *Fig.* 1, Plate XIII, taken at the entrance of the second cervical dorsal roots, shows the relations of these parts. The ventral column is rather smaller in comparison to the lateral and dorsal columns. It receives fibres from the ventral cornu, *a*, and from the anterior commissure, *b*. The lateral column is uniform in texture and is not susceptible to a division into pyramidal and direct cerebral tracts by any markings on the sections. It receives a constant supply of fibres from the whole extent of the ventral column. The dorsal columns show a decided difference in texture in different parts and can be easily divided into the dorsal or Burdach's columns, *g*, dorsal median, or Goll's columns, *h*.

In Goll's columns the transverse section shows but a small amount of neuroglia and the section is entirely made up of nerve fibres, as will be seen from Plate XIII, *Fig.* 7, while *Fig.* 6 of the same plate shows the structure of Burdach's columns and the lateral and ventral

columns to be quite different in having much larger fibres with a considerable amount of surrounding neuroglia.

The ventral root-zone is represented in Plate XIII, *Fig.* 2, and is found to spread out over the greater part of the lateral aspect of the cord. The ventral root does not leave the cord as a distinct bundle, as is the case with the dorsal root, but is formed from an extension of the fibres from the whole side of the ventral cornu, which radiate to the surface of the cord and then converge to the ventral root.

The dorsal root enters as a large bundle. Part of its fibres pass into the dorsal root-zone or Burdach's columns and part pass directly into the dorsal cornu and there enter the cells of the gray matter, while part pass directly to the opposite side through the posterior commissure.

The distribution of the gray matter is essentially the same as that of the rabbit. The ventral cornu is rather broad but very short and contains two groups of multipolar cells. One median group (Plate XIII, *Fig.* 1, *a*, *Fig.* 3, *Fig.* 4, *b*, and *Fig.* 8,) is situated at the median angle of the cornu, having cells from .015 to .02 mm. in transverse diameter. These cells send off processes to the ventral columns, which eventually pass into the ventral roots, also processes which seem to pass to the dorsal cornu, and some which pass through the ventral commissure to the opposite side.

The other cell group (Plate XIII, *Fig.* 4 *c*, *Fig.* 9,) is situated external to the first and forms a lateral nucleus The cells resemble those of the median group very closely and send their processes in the same directions.

The cells of the gray matter of the dorsal cornu are much smaller than those of the ventral. They occur in greatest numbers in the cervix of the cornu (Plate XIII, *Fig.* 1, *b*, *Fig.* 2, *Fig.* 4, *a*, *Fig.* 5.) These cells are from .005 to .01 mm. in transverse diameter and are multipolar in form. The processes to which they give origin follow the direction of the fibres in which the cells are imbedded, but whether they are simply the nodal points of these fibres and do not represent true cells may be questioned. They are nucleated and, except in size, resemble very closely the motor cells of the anterior cornu. Besides these distinct cell groups there are also numerous cells scattered rather irregularly throughout the gray mass, and at the exits of the ventral roots. These cells, which lie lateral to the central canal, increase greatly in number and size and appear to form a large nucleus

occupying the whole ventral cornu and middle gray portion. (Plate XIII, *Fig.* 4, *d.*)

Passing cephalad into the medulla, in a cross section taken just caudad to the decussation of the motor tracts (Plate XIV, *Fig.* 1,) the general arrangement of the gray and white matter is quite similar to that of the cord in the cervical region. The columns of Goll are very much reduced in size, being compressed, as it were, by the decussation of the motor fibres and, a little further cephalad, form the *funiculus gracilis.*

The dorsal caput cornu is much enlarged and the gray matter extends laterally almost to the surface. The gray matter is everywhere filled with cells of the multipolar type, which are scattered almost uniformly through the substantia gelatinosa and the dorsal cornu especially is charged with nutritive corpuscles. This uniform distribution of cells through the gray matter seems to accompany the reduction in the number included in the various nuclei. The nucleus of the ventral cornu (Plate XIV, *Fig.* 1, *b,*) is still quite manifest, but the second group, which lies somewhat lateral to the first, has lost its identity in the general distribution of cells.

The number of cells present in the median nucleus (Plate XIV, *Fig.* 1, *d,*) seems to be also somewhat reduced. The cells which were so conspicuous in the neck of the dorsal cornu, (Plate XIII, *Fig.* 4, *a,*) are also much scattered, while a remnant of them seems to persist though crowded more dorsally, (Plate XIV, *Fig.* 1, *c.*) We notice also the accumulation of a few cells, somewhat external and lateral to the nucleus of the ventral cornu which is the beginning of a large ventro-lateral nucleus extending cephalad, (Plate XIV, *Fig.* 1, *e*, *Fig.* 5, *c.*)

The expansion of the gray matter seems to be due to the insertion of a large number of nerve bundles which are distributed through the gray matter and run longitudinally in the medulla, beginning the formatio reticularis of the medulla a little further cephalad. In the section under consideration there is also shown the exit of a small bundle given off to the eleventh nerve root, (Plate XIV, *Fig.* 1, *a.*) The fibres seem to be derived from the generally distributed cells.

Passing a little more cephalad in a section taken at about the first fourth of the decussation, (Plate XIV, *Fig.* 5,) we find that the nucleus of the ventral cornu has entirely disappeared, while the ventro-lateral nucleus (*Fig.* 5, *c,*) is much enlarged and is composed of cells of the multipolar type, measuring from .03 to .05 mm. in diameter (Plate

XIV, *Fig.* 3.) The median nucleus (*Fig.* 5, *b*,) still continues, and there is a gradual separation of the cells of the nucleus into a dorsal and ventral group, as will be seen by reference to *Fig.* 6, *d*, and *e*, of the same plate. The remaining portions of the gray matter are about as in the previous section. At about the middle of the decussation we find that the median nucleus has entirely differentiated into two distinct nuclei, the ventral being the caudad extension of the nucleus of the twelfth nerve, (Plate XIV, *Fig.* 4,) and the dorsal, the nucleus of the eleventh nerve. The pyramidal tracts in decussating and passing dorsad are divided up into a great many fasciculi, and these are thickly interwoven with each other in crossing and also with the fibres of the gray matter.

The surface of the fasciculi is very thickly covered with nutritive corpuscles, even more so than the gray matter at this point. The gray matter contains many longitudinal bundles which are seen here in cross section and which mark the first appearance of the *formatio reticularis* of the medulla. In this section also there appears for the first time a small ventral cluster of cells, (Plate XIV, *Fig.* 6, *a*,) which marks the beginning of the *olivary body*. These cells are rather smaller than those in any nucleus previously discussed, measuring about .02 mm. in diameter. They tend to be bipolar and flask shaped in form and the processes start more abruptly from the cell body. Plate XIV, *Fig.* 2, represents this entire nucleus.

It may be noted here that our study has led us to the opinion that most of the so-called flask-shaped and unipolar cells are in reality cells of the bipolar type which have been sectioned obliquely to their axis. This will account for the fact that many of the flask-shaped cells are non-nucleated. We do not mean to imply that there are no unipolar cells, for those do in some cases undoubtedly exist, but that in a nucleus the cells all tend to be of the same type and it is with doubt that we accredit the presence of unipolar cells in a multipolar nucleus.

Passing cephalad from this level, the medulla, enlarges rapidly, the *canalis centralis* is flexed dorsad and rapidly expands into the fourth ventricle. There is an aggregation of gray matter towards the median portions and on the floor of the ventricle. The white matter is limited to a narrow zone around the lateral and ventral surface and the reticular formation.

In a section taken at the level of the twelfth nerve, (Plate XV,

Fig. 1,) the fibres of the twelfth enter on the ventral surface just lateral to the pyramids, *k*, pass through the olivary body, which attains its maximum development at this point, and then through the formatio reticularis to its nucleus, *b*, on the floor of the fourth ventricle. The cells of this nucleus are of the multipolar type, measuring from .05 to .06 mm. in length, having nuclei about .01 mm. in diameter, with nucleoli. The axis cylinder process generally passes into a bundle of fibres leading to the root of the nerve. *Fig.* 5, Plate XV, presents a magnified view of the entire nucleus as it appears at this point. Just laterad to this is situated the nucleus of the tenth nerve Plate XV, *Fig.* 1, *a*, and a magnified portion of the same *Fig.* 2, of the same plate. The cells of this nucleus are somewhat smaller than those of the twelfth, though of about the same number and form, Just laterad to this nucleus is a large cluster of small cells which is evidently very closely associated with it.

Still laterad we find a large group of cells which may be divided into two nuclei. The lateral one, (Plate XV, *Fig.* 1, *c*,) constituting the *cuneate* nucleus, contains cells measuring about .03 mm., imbedded in a very dense neuroglia (Plate XV, *Fig.* 6,) while the cells of the median portion are very much smaller and are more numerous, constituting the *clavate* nucleus.

The formatio reticularis is very largely developed and rather abundantly provided with cells which are of the multipolar type, measuring about .04 mm. aud sending their processes in the general directions of the fibres in which they are imbedded. Plate XIV, *Fig.* 4, will serve to illustrate their manner of distribution between the longitudinal fasciculi of the reticular formation.

There is a marked decussation of fibres in the lower portion of the raphe in which are found multipolar cells of about .02–.03 mm., which here form a considerable nucleus, (Plate XV, *Fig.* 1, *e*, and a magnified view of the same, *Fig.* 3, of the same plate.) The decussation is of fibres from the olives, while large bundles appear to pass through the olives and thus around into the *restiform* tracts. A small lateral nucleus is also present.

As we pass cephalad, in a section at the level of the entrance of the tenth nerve root, (Plate XVI, *Fig.* 1,) we find the nucleus of the twelfth nerve, *c*, still represented on the floor of the ventricle and the nucleus of the tenth, *b*, very closely associated with it. The olives are much reduced in size, the nucleus of the raphe in the decussation

not so largely charged with cells, the cuneate and clavate nuclei have disappeared, the lateral nucleus is still present, while the cells of the formatio reticularis are much more abundant and indicate the beginning of a large median nucleus which is quite conspicuous in the next section, (Plate XVI, *Fig.* 2, *e.*) This section is taken still farther cephalad and is chosen at the entrance of a few fibres of the ninth nerve root, (*Fig.* 2, Plate IX.) Most of the fibres of this nerve turn soon after entering the medulla and pass into the longitudinal fasciculi; some, however, seem to lead directly into a small nucleus, *a*, which we term a nucleus of the ninth nerve. At this level we find the cells of the lateral nucleus increasing in number and size and forming quite a large aggregate which can easily be traced as the caudad extension of the seventh nerve nucleus. We have in this section also the first few fibres of the eighth nerve passing in above the restiform body to a large mass of gray matter densely packed with small cells, which we shall term the internal nucleus of the eighth nerve.

The next section is taken at about the level of the middle of the entrance of the eighth nerve and at the union of the cerebellum with the medulla by the *pedunculus cerebelli*, (Plate XVI, Fig. 3.) The eighth nerve enters as a large bundle, *i*, and just within the border of the medulla is located the nucleus of the root of the eighth nerve, *c*, composed mostly of rather small cells.

Following the fibres as they pass into the medulla we find that some of them pass dorsad to the restiform body, *f*, and enter Deiter's nucleus, *b*, in the peduncle of the cerebellum and some turn directly into the cerebellum. Of those fibres which pass ventrad to the restiform body, part turn dorsad and enter Deiter's nucleus from below and perhaps pass through the nucleus into the cerebellum.

The remaining fibres pass through a reticular formation and enter the internal eighth nucleus which is on the floor of the fourth ventricle at *d*, Fig. 3, Plate XVI The cells of Deiter's nucleus are of the ordinary multipolar type, measuring about .05 mm. in length. The entrance of the eighth root is also shown on Plate XVI, Fig. 6, as is seen in a longitudinal section taken parallel to the base of the medulla. As most of the fibres pass dorsad upon entering the medulla the only nucleus of the eighth shown at the level of the entrance is the nucleus of the root, *b*, of the figure.

Besides the nucleus of the raphe and adjacent formatio reticularis, *e*, of the section, (Plate XVI, Fig. 1,) the only other group of cells

which we will consider, is the large nucleus of the seventh nerve seen at *a*. This nucleus occupies a ventro-lateral position and is quite large with fibres passing from the cells collected into definite fasciculi, which pass dorso-cephalad almost to the floor of the ventricle where they are united into two or three large bundles and turn upon themselves, forming the knee of the seventh nerve, seen in cross section, (Plate XVII, Fig. 1, *f*, and Fig 2, *b*.) The cells of this nucleus are of the multipolar type, with numerous processes and large nuclei. They measure about .07 mm. in length with nucleus .01 mm. in diameter. A magnified view of a small portion of the nucleus is shown by Fig. 4, Plate XVI. Fig. 6, of same plate shows at *e*, the position of the large fascicle of the seventh seen in cross section.

Before leaving the eighth root, it is well to examine one more section taken farther towards the cephalad margin of the root. Plate XVIII, Fig, 1, at *a*, represents the entrance of the fibres, with the root nucleus at *b*. In this section the restiform body has passed into the cerebellum to the *vermiform process* (Ranney), and the fibres of the eighth are not here divided, but pass directly into Deiter's nucleus and upwards into the cerebellum, while the internal nucleus is reduced to a very small cluster of small cells. That fibres of the eighth pass into the cerebellum is without question. We observe also at this level the nucleus of the sixth at *d*, and the forward extension of the olivary body at *e*. The formatio reticularis comprises the largest part of the section.

Examining a section at the level of the entrance of the seventh, (Plate XVII, Fig. 2,) we are able to trace the large bundle of the seventh, *a*, through the formatio reticularis above and medianly to the nucleus of the sixth, *d*, to its flexure or genu. In the same manner the path of the fibres of the sixth nerve are easily traced to their nucleus, *d*, on the floor of the ventricle. The cells of this nucleus are about .05 mm. in length and have their axes in the direction of the entrance of the fibres into the nucleus. (Plate XVII, Fig. 5.) The olivary body, *e*, is also present in this section as a nucleus on the ventral side of the medulla, its cells measure about .02 mm. and have numerous processes which start abruptly from the cell, thus giving them an even outline in appearance under a low power There is a very evident decussation with its fellow of the opposite side. Fig. 2, Plate XVIII, gives a magnified view of these cells.

The next section considered is taken at the level of the caudad margin of the fifth root, (Plate XVIII, Fig. 3.) The scale upon which

this figure is drawn is a little smaller than the previous figures of the medulla in order to represent the full section and show the relation of the cerebellum to the medulla at this point.

The entrance of the fifth nerve, *a*, is shown in quite a number of sections of the series as the diameter of the root is so great, but we here consider only two of this number. The one under present consideration shows the fibres of the fifth nerve passing to a large motor nucleus, *b*, and to a sensory nucleus, *c*, also fibres passing to the gray mass on the floor of the ventricle. The motor nucleus is charged with very large multipolar cells with numerous processes and large nuclei. For form and size, compare scale on Plate XVIII, Fig. 4.

Passing to the next section (Plate XVIII, Fig. 1,) taken at the middle of the fifth root, we find about the same distribution of fibres and nuclei. In no case are fibres of the fifth nerve traceable to the cerebellum directly. The beginning of the large nucleus of the pons, *d*, also appears in this section.

Fig. 6, Plate XVIII, presents a longitudinal vertical section of the medulla and cerebellum, showing the entrance of the fifth nerve, *a*, and the eighth nerve, *c*, with its root nucleus, *d*. In the longitudinal basal section of the medulla at the level of the eighth nerve (Plate XVI, Fig. 6,) the entrance of the fifth nerve, *c*, is also seen with a large bundle of fibres extending caudad and some turning to a nucleus (probably motor) at *d*.

At the entrance of the fourth nerve, in the section taken on a level with the valve of Vieussens, the fibres of the fourth enter and decussate with those of the opposite side, and then pass ventrad and cephalad to their nucleus. The nucleus of the pons, *a*, is very large and almost entirely surrounds the pyramidal tract, *g*. The cells of this nucleus measure about .02–.03 mm. and are imbedded in a dense neuroglia, their processes are short and the cells under a low power have a quite regular outline and bear a striking resemblance to the cells clustered in the central gray mass bordering the aqueduct of Sylvius, as will be seen by comparing Figs. 4 and 5, of Plate XVIII, taken from the two regions. There appears to be another aggregate of cells in the central gray mass at *c*, the cells of which are quite small, flask-shaped, and bipolar, mostly measuring about .01 mm. The raphe and the formatio reticularis are here highly charged with cells and present the appearance of one large nucleus.

Horizontal sections, including the anterior portion of the medulla

and the entire higher portions, afford opportunity to trace the connections of the structures already described with the cerebral ganglia.

Nuclei and tracts of the higher portion of the medulla and crural region, as seen in horizontal sections.

The bladder cells of the dorsal root of the trigeminus. These remarkable cells have already been referred to. They seem to have been first recognized by Stilling, who regarded them as forming an accessory nucleus of the fourth nerve, in whose tract they nearly lie. Stieda (Zeitschrift f. wiss Zoologie, Band XX,) falls into a worse error, regarding these cells as the true nucleus of the fourth, and failing to discover the tract extending from the root cephalad, (*Loc cit.* Plate XX, Fig 44.) Stieda's drawing is exceedingly conventional, so far as concerns cells and nuclei.

Meynert (Striker's Histology, Am. Ed., p. 705,) describes the cells in question as follows:

"The cells from which spring the above mentioned roots of the fifth pair, differ strikingly, in regard to their shape, from the cells in the common nucleus of the oculo-motor and trochlearis. The former are inflated, bladder like, and furnished with but few and slender processes, which project abruptly from the cells like a straw from a soap bubble. The latter are large, like the former, but slender, and rich in processes whose calibre passes by gradual transition into that of the cells. The former resemble the cells of the spinal ganglia, the latter those of the anterior cornua of the spinal cord."

"Even within the limits of the upper corpora bigemina, the central tubular gray matter encloses the nuclei which give rise to the motor nerve roots referred to (oculo motor, etc.), which lie more or less near the median line; also a laterally disposed sensory nerve tract, the roots of the fifth cranial nerve. The fibres composing these roots originate at the outermost border of the gray matter which surrounds the aqueduct of Sylvius in small collections of large bladder-shaped cells 60 micr. in length and 45-50 micr. in breadth."

In *Arctomys* the disparity in size between the cells of the nuclei of the fourth nerve and these bladder cells forbids comparison, otherwise the remarks quoted apply substantially. The deduction which Meynert attempts to draw regarding the relative position of sensory and motor nuclei in the medulla seems forced in this case, being based on the pure assumption that these cells are sensory, while the differ-

ences between any known sensory cells and those in question are certainly as striking as their resemblance.

Similar cells have been described by Belonci, in birds, Stieda in the turtle, and Herrick, in the alligator. As a matter of fact, no substantial basis exists for determining the function of these cells. Their similarity to Purkinje's cells of the cerebellum gives some force to the suggestion that there may be similarity in function if not in origin, though the resemblance is still greater to the cells of the ganglion of Gasser.

These bladder cells are especially well seen in the horizontal sections passing through the nuclei of the third and fourth cranial nerves. (Plate XIX, Fig. 2, *Bc*, *Bc'*, Fig. 4, *b*.)

These cells are .05–.07 mm. in diameter and of a baloon or flask shape or polyhedral. The processes are few, and abrupt, and give rise to a very large fibre. Such cells are first encountered in the base of the tectum opticum, near the highest part of the nates and are sparsely scattered in the tract which passes in a gentle curve laterad and caudad and at the same time, somewhat ventrad, to form a disperse tract about the aqueduct and thence caudad to the anterior part of the fourth ventricle. Here the cells are most numerous and lie peripheral to the strong motor nucleus of the fifth, which lies near the ventricle. Although the two sorts of cells commingle in places, there is never any difficulty in distinguishing them. The general relation is always that described. The tract can be traced laterad and ventrad and the nucleus itself describes a strong lateral curve at the point of departure of the root tract, while scattered cells of this type can be traced to the point where the fibres are lost in the common root of the fifth.

Motor nuclei of the trigeminus. The cephalad portion of the trigeminal motor system is quite complicated. The highest recognizable portion is the elongate cluster bordering the caudad portion of the aqueduct and the cephalad part of the fourth ventricle. The cells are figured, (Plate XIX, Fig. 4, *a*,) and are of the usual motor type, measuring .05–.06 mm. in length, by .02–.025 mm. in width. The prevailing direction of the principal processes is caudad, *i. e.* toward the root, the opposite extremity being multipolar.

A second nucleus lies ventro-laterad from this one and appears in horizontal sections through the highest portion of the root of the fifth. It lies nearly opposite the caudad part of the pre-pedunculus cerebelli and is of circular outline and about fifty cells lie in one horizontal

plane of its middle portion. The cells are fine examples of the multipolar type.

This nucleus does not extend dorsad to the level of the sixth nucleus, which is a relatively broad zone with little dorso-ventral extent. The cells of the sixth nucleus lie with their axis from the median toward the lateral line and their fibres evidently decussate.

The same horizontal section (VII 6-19) displaying the nucleus of the sixth shows the knee of the seventh, lying between it and the median line and enveloping it anteriorly and posteriorly, as already described.

Scattered cells, apparently of the trigeminal system, lie dorsad to the structures just described.

Ventrally, the ventral nucleus of the fifth divides into two ill defined clusters, the medio-caudad portion being approximated to the root tract of the seventh, which latter subdivides into a larger cephalad and smaller caudad portion.

Nucleus of the pons. The whole ventral part of the pons is filled with cells, which here and there collect into considerable and distinct nuclei. The cells are relatively short and paraxial with numerous processes, the largest of which pass transversely, *i. e.* in the direction of the pons fibres. These cells are comparatively small, but their nuclei preserve a good size, thus: cells .030–.035 in. diameter, nuclei .008 mm. The fibres can be traced from cells of the caudad portion of the nucleus laterad and caudad for considerable distances to the root of the fifth. (Plate XIX, Fig 3.)

The sections at the level of the motor nucleus of the seventh show that a part of the anterior portion of the pons nucleus is cut off by the passage of the latero-ventral strands of the pyramids and lie between those bundles and the pre-peduncular tract from the cerebellum. Fibres from the cluster in question pass to unite with a nucleus of similar cells at the immediate roots of the fifth.

The seventh nucleus, as seen in horizontal sections at the level of the emergence of its root is divided into three portions lying parallel to the median line. The cells are beautiful illustrations of the multipolar variety (Plate XIX, Fig. 5,) and afford ample suggestion, if not proof that the fibrillar terminations of the processes described by authors are due to the disposition of connective tissue web in which they hang.

The Cerebellum. Before adverting to the few observations we

have made upon the cerebellum it may be proper to enumerate some of the results of the late investigations of Golgi (Sulla fina anatomia degli organi centrali de sistema nervosa, 1886,) of Ramon y Cajal (Revista trimestrial de Histologia normal y patologica, Aug., 1888,) and, more recently, of Prof. Koelliker, which seem not to have attracted the attention they deserve in America.

It remains to be seen how far the metallic impregnation upon which Golgi's method rests, develops normal structures and how far it may be relied on to differentiate solely nervous tissues. Really successful hæmatoxylin and cochineal stains will reveal most of the details, though less conspicuously, and are not open to the objection that the stain may be a more or less mechanical precipitate rather than a truly selective stain.

Golgi's chief discoveries are the following: The Purkinje's cells have two sorts of processes, the peripheral protoplasmic processes, which subdivide almost indefinitely, but do not terminate in nerve fibres or a nervous reticulum, and a median axis-cylinder process, which is occasionally furnished with lateral branches.

In spite of the numerous subdivisions of the process, anastamosis is said never to take place between different cells. The Purkinje's cells lie between the outer or molecular zone and the deeper or granular zone.

In the former layer Golgi recognized small cells of variable form with both branching and axis-cylinder processes, which latter also subdivide but do not reveal their ultimate course.

In the granular layer Golgi found small nerve cells with a delicate axis-cylinder process and short and few protoplasmic processes extending to granular aggregates. There are also, still more rarely, larger cells of a fusiform shape and very numerous branches of the axis-cylinder.

Golgi claims that the medullated nerve fibers in the white layer, and especially in the granular and molecular layers, anastamose largely. This latter fact is not substantiated by Cajal, who, moreover, considers the axis-cylinder of the granular cells, and of the small cells of the molecular layer as well as those of the larger cells of the granular layer as non-medullated.

Koelliker summarizes his own observations in the following aphorisms:

"All free, non-medullated processes of nerve-fibres are, in my

opinion, undoubtedly to be regarded as centrifugal. All medullated fibres springing from cells are centrifugal. Branching protoplasmic processes of cells are perhaps centripetal, while the so called nervous processes of these, even where non-medullated, may be centrifugal."

(1.) The granular layer contains, besides scattered ganglion-cells, innumerable multipolar nerve cells, both larger and smaller.

(2.) The very numerous small granular cells have only short protoplasmic processes terminating at the end in a brush. The very delicate nervous process usually springs from one of the protoplasmic processes and passes vertically into the molecular layer, where it divides into two unbranched fine fibres running horizontally and longitudinally.

(3.) The large granular cells are less numerous and their densely branched fibres may penetrate deep into the white zone. The nervous process is abundantly branched in a small area and seems not to pass beyond the granular layer.

(4.) Purkinje's cells do not anastamose. The nervous process has a few fine branches ascending to the molecular layer.

(5.) The small cells of the molecular layer are separable into outer smaller cells and the inner or basket cells, The former are provided with strongly branched protoplasmic processes and a nervous process, the course of which is not yet known.

The basket cells have long, strongly branched protoplasmic processes, which may extend to the outer edge of the molecular layer. The nerve process is very long and passes transversely over the bodies of the Purkinje's cells and here and there sends downward perpendicular processes which subdivide and envelop the body of the Purkinje's cells in a basket-like reticulum.

(6.) The medullated fibres in the adult cerebellum do not divide, except rarely in the molecular layer.

(7) The results of Golgi's method reveal no actual anastamosis of cells and does not suggest any ground for assuming the existence of a nervous reticulum.

Our own work has been too superficial to justify extended criticism of the results quoted, but we venture a few suggestions

1st. Successful hæmatoxylin staining brings out the nervous elements with certainty and reasonable clearness. Golgi's method is liable to introduce error, in that the staining involves connective tissue elements and is variable.

2d. Our preparations show with perfect clearness in Purkinje's cells a basal process and one or more strong peripheral processes, which latter seem to us to be continuous with a system of transverse fibres lying in the molecular layer. The molecular layer contains sparsely scattered Deiter's ("glia") cells which stain deeply with hæmatoxylin and cells of the connective tissue system, which include those mentioned by Koelliker.

3d. The fine branching processes of peripheral and basal processes of Purkinje's cells are probably not nervous.

4th. The "basket cells" of Koelliker are almost certainly of connective tissue character.

5th Haematoxylin staining brings out quite evidently the large nerve cells of the granular layer, but we suspect that the ramifications described by Koelliker are, in this case also, the result of differentiation of the connective-tissue frame work of the cell.

6th. Branching of the nerve fibres of the white central layer is rare.

We are driven to reject the results of the Golgi method from the resemblance of the structures produced to those constantly encountered and demonstrably the result of the intricate meshwork of connective tissue in the form of hollow sheaths enveloping the cells. Each nerve cell is loosely enveloped in such a sheath, which can be separated by proper treatment, and this sheath is produced in numerous directions into tubular or conical projections which may branch and ramify extensively. The same sheath may expand in a nodular manner to envelop another cell or embrace a fibre and may ultimately terminate in a number of brush-like fibrils attached to some membrane or fibrous strand. We believe this explanation is competent to account for many of the complicated structures described by Golgi.

In the great majority of Purkinje's cells, for example, we can trace a single strong process (these are numerous in the opossum), peripherad nearly to the surface, with little diminution of size, and perfect distinctness and with no lateral branches whatever. Hundreds of such cases are before us where a perfectly distinct uniform branch can be followed to near the surface and another of smaller diameter medianly through the granular layer. The nervous protoplasm in the cell and in both fibres is colored similarly.

Furthermore, no rational interpretation of the structure described by Koelliker seems possible, while the arrangement we observe seems

to coincide with the physiological requirements of the organ. The great simplicity of these cells in Arctomys adapts it for their study. We incline to accept Beevor's suggestion in part, *i. e.*, that the ascending processes of Purkinje's cells turn at right angles and connect with fibres leading to the brain

The Mesencephalon.

We preface our own observations with Stieda's account of the corpora quadrigemina in the rabbit, which is as follows:

"The peduncular region has the following nuclei. Above the united pyramid tracts and lower longitudinal bundles is a cell group on either side, each of which consists of two parts. The under (ventral) portion is the larger and contains many small cells (.012–.16 mm) in a granular ground mass; the upper, smaller portion has large angular cells of .14 mm. diameter. This nucleus may be called *Nucleus pedunculari*s. On the lower margin of the central gray, thus near the floor of the aqueduct, is the oculomotor nucleus of either side. It consists of cells of moderate size (.04 mm.) and angular form. Between the two nuclei and near the floor of the ventricle are numbers of small triangular or fusiform cells. The fibres from the oculomotor nucleus are very numerous and pass through the nucleus peduncularis and between the bundles of the anterior columns to their roots."

"The central gray of the posterior corpora quadrigemina is limited by fibre tracts. Laterally the nucleus of the trochlearis is mingled with these fibres. [The author's figures are here derived from the dog, and we are left in doubt as to the condition in the rabbit, though he explicitly states in a foot-note elsewhere that he introduces references to drawings of other brains that are described only where they are similar.] The nerve-fibres of the corpora quadrigemina are partly transverse, which decussate in small bundles above the aqueduct, and partly oblique bundles."

"The central part of the nates is, like the other gray matter, composed of small nerve cells scattered in a granulate mass, but the superficial portion exhibits distinct interstratification of a white zone parallel to the surface. With high powers an outer zone devoid of cells, may be seen; below this a zone of granulated substance with scattered small cells, then a layer of numerous transversely cut bundles of fibres separated by gray substance, containing stellate nerve cells (.008–.012 mm.) with well-developed processes."

"Then follows a layer of gray matter, with associated fibres. Between the prominences is a considerable commissure of fibres which lose themselves among the longitudinal fibres."

" The fibres on the surface of the corpora quadrigemina I unhesitatingly regard as the real roots of the optic nerve."

(In this latter statement Steida is doubtless mistaken.)

The sections figured on Plate VIII, Figs. 1, 2, and 3, and Plate IX, Figs. 1-5, will convey an idea of the changes observed in successive sections.

Fig. 1, Plate VIII, indicates the structure of sections at the posterior commissure. The nates above are cut near the anterior (cephalad) border. They are at this point receiving fibres from the latero-dorsal optic tract. Some fibres associated with the latter, however, dip downward and medianly to interdigitating masses of gray matter in the lateral aspects of the posterior commissure, Fig. 2, *c*. (See Fig. 7.) Above the commissure is a protuberance of gray matter, looking toward the inter-natal cleft, which resembles the nates and seems to have no special significance. Below the commissure are masses of gray matter, composed of small cells of various forms, though chiefly pyramidal, with long processes, which in position as nearly resemble the colliculi as any structures of lower vertebrates. The bundles entering the posterior commissure diverge rapidly and arch over the last mentioned body, soon passing caudad out of the section. The posterior commissure seems not to be a true commissure but, in part at least, a decussation.

In the median line below the aqueduct there is a collection of cells (Fig. 9,) of the fusiform variety, occupying the position of the raphe. Beneath the optic tract is a large mass of gray substance (corpus geniculatum externum) perforated at intervals by well-defined tracts, which externally lead obliquely toward the periphery and medianly dorsad. The cells are scattered and small, but very acutely angular and of a multipolar variety. A similar body (corpus geniculatum internum) lies below it and only separated by a tract of irregular fibres. Its fibres pass cephalad and medianly. Still another small but rather definite nucleus lies in the latero-ventral region within the longitudinal ventral bundle, which here is peripheral. The entire central portion (*formatio reticularis*), is a reticulum of cells and fibres surrounding longitudinal disperse fascicles. A few very large multipolar cells are scattered in the meshes with the peculiar radiating con-

nective tissue fibrils due to the structure just described. A bundle passing from above nearly parallel to the median line and obliquely caudad, seems to be Meynert's bundle, as seen in longitudinal sections.

Sections caudad (Fig. 4,) indicate the rudiment of the ventricle of the optic lobes so prominent in reptilia, etc. The fibre tract above this may be distinguished as the commissure of the optic lobes or simply optic commissure.

Sections posterior to the nates and therefore passing through the testes near their base and nearly parallel to the base are, because of their position, at right angles to the nates.

(Section immediately following Fig. 5, Plate IX, VI-*c*-25.) The outline of the section is approximately semi-circular, the upper surface being truncate. The aqueduct which lies near the dorsal aspect is rhombic with the angles produced in the horizontal and vertical planes. The bridge is abruptly separated from the peduncular portion, except ventrally, where its fibres separate into fascicles inter-digitating with each other and leaving intervals which are filled with densely nucleated gray matter. The dorsal half of the section is composed of nearly homogeneous, finely nucleated gray matter, in which are no well-limited nuclei-portion of testes. The latero-dorsal angles are occupied with obscure and ill-defined longitudinal tracts. The lateral aspects of the dorsal half are occupied by arching fibre tracts passing ventrad which seem with little doubt to be backward continuation of fibres descending from the nates. The tract disappears by passing caudad out of the section at a point dorsad to a well-defined nucleus lying just laterad to the ventral pyramids, which latter here form strong bundles with oval sections. The nucleus just mentioned (pons nucleus,) is similar to the gray matter filling the interspaces between the pons fascicles.

Upon the dorsal aspect of the ventral pyramids is another small nucleus, having a narrow encircling band of gray, with the longer axes of the cells parallel to the plane of section and at right angles to the fibres.

Above this nucleus is a small circular cluster on either side near the median line, consisting of larger multipolar cells. Still dorsad and in the ventral aspect of the dorsal longitudinal fascicle, is a larger nucleus on either side, likewise circular in outline and densely packed with cells of median size and irregular contours. The area immediately surrounding the aqueduct is homogeneous and sparsely sprink-

led with small cells, except along the raphe, where is the usual nucleus, and a short distance on either side, where a disperse nucleus in the position of the fourth still remains. In the lateral parts of the area about the aqueduct are a few of the large, nearly spherical or polygonal cells. ("Bladder cells" of descending tract of the fifth.) The tracts of the fourth nerve appear as two or three transversely cut bundles at some distance laterad of the aqueduct. The dorsal longitudinal fasciculus lies about one-fifth the way from the aqueduct to the ventral surface and its lateral portions curve ventrad to almost unite with the ventral tract.

Passing cephalad a short distance, the nucleus of the fourth nerve appears immediately dorsad to the dorsal longitudinal fascicle. It consists here of very irregular polygonal, multipolar cells measuring about .027 mm., while the nucleus of the raphe consists of a dense aggregate of fusiform elements immediately ventrad to the aqueduct, which at this point is a transverse slit. The dorso-lateral tract now forms a conspicuous prominence ventrad to the nates fissure. The nates posteriorly exhibit a conspicuous radiating structure of the cortex which appearance is heightened by the very numerous blood vessels which pass toward the centre in a direction parallel to that of the nerve chains. Medianly, sections (VI *c*-20) display a number of fibre tracts in section, which are doubtless continued from the optic tract and enter obliquely from the antero-median aspect. Proceeding cephalad these bundles increase in number.

A comparison of the nates with the optic lobes of lower animals reveals what at first seems a fundamental difference. While in reptiles and birds the fibres of the optic tracts pass directly to the periphery of the tectum opticum, in mammals these fibres appear to pass into the deeper portions. In reptiles pretty definite chains can be traced from periphery to base of the tectum with insulating, columnar connective tissue apparatus which forcibly suggests the arrangement in the retina. Nothing of this sort distinctly appears in the mammalian nates. The reptilian tectum is characterized by the presence of a few scattered cells of great size which resemble greatly Purkinje's cells of the cerebellum and are especially abundant in the deeper layers of the interval between the two tecti. Such cells have not been carefully described in mammals, hitherto, to our knowledge, though figured by Bellonci in birds and by Herrick in the alligator, and discovered in great abundance in the same portion of the brain of the turtle, by Coppock. In

the opossum, one of us has found these cells widely distributed through the corpora quadrigemina and thalamus about the roof of the third ventricle and aqueduct, as well as the tectum opticum. We have thought these cells indicative of a low or primitive condition, especially as these cells seem in Didelphy to be devoid of processes. There seems to be no doubt that the cells of this sort lying behind the roots of the fourth nerve constitute a nucleus of the fifth, and the connection of these cells with the entirely similar cells of the tectum opticum is clearly suggested by the course of the fibres as already pointed out. What the reason for the dispersion of these cells so irregularly through the higher regions may be cannot be determined, nor yet the definite connections existing between these large cells and the adjacent structures. See Fig. 3, Plate IX, where such cells should be indicated in the outer lateral border of the gray matter surrounding the aqueduct. (See Osborn, Journ. Morph., Vol. II.)

Horizontal sections through the mesencephalon, etc.

The lowest (most ventrad) sections passing through the pars peduncularis exhibit the lateral fibre tracts formed by the pyramids, within which lie the cross sections of the 8-10 bundles of the oculomotor. Immediately in front of the pons medianly is a circular prominence occupied by the interpeduncular nucleus and transverse decussating fibres. This body seems to be merely a nodular prominence of the raphe. The body in question lies 4 mm. behind the posterior margin of the tuber cinereum. The few cells occurring in the nucleus are small flask-cells. At a slightly higher level there appear two distinct nuclei, one seeming like the forward continuation of the pons nucleus and lying caudad to the tracts of the third, the other slightly laterad and cephalad to these tracts. The latter consists of multipolar cells of medium size imbedded in a dense reticulum which seems to be merely the cross section of Meynert's bundle.

At the ventral level of the peduncular nucleus the eleven fibre bundles of the third root have nearly reached the median line. The nucleus is disperse and extends cephalad some distance beyond the nerve roots. At this level there is a marked decussation of the longitudinal fibre bundles immediately behind the third roots. The decussating fibres curve laterad and caudad, passing in this section to the nucleus at the base of the peduncles of the cerebellum.

Fig. 2, Plate XIX, sufficiently illustrates the topography of a hor-

izontal section at the level of the third and fourth nuclei. A dense nucleus, (*N. interpatheticus*,) occupying the region of the raphe caudad to the fourth nucleus is conspicuous. In higher sections the emergence of the fourth root tracts by a number of small bundles describing an abrupt outward curve, is well shown. The interpathetic nucleus above described now lies in the median plane between the nuclei. While no decussation was observed, we are convinced that fibres from the third are given off to tracts passing caudad and laterad.

The relations of the tegmentum with the corpora quadrigemina may be best studied in longitudinal vertical sections. (Plate XIX, Fig. 1.) The nates are nearly quadrangular and inclined posteriorly while the testes lie nearly at right angles to the former and do not reach one-half the size. Fibres from the optic tracts spread out upon the surface of both anterior and posterior corpora and are followed with difficulty.

In Didelphys the testes are much more prominent than the nates, and contain relatively more gray matter. The tectum proper is not developed below the lateral plane passing through the third nerve nuclei. In this plane there appear to be five lateral nuclei, three in the thalamus and two in the mesencephalon. The median part of the section is filled with cells, constituting one unseggregated nucleus. We have been able to convince ourselves that the fibres from the optic tracts do not spread out upon the surface of the tectum, but rather are over-capped by a cortex similar to the cerebral. Thus the portion above the aqueduct is separable into four gray layers with three white zones bounding them. The innermost gray zone is immediately surrounding the ventricle and is filled with small cells. (Plate IX, Fig. 3, etc.) This zone is limited by the decussating tract of the nates, in which are found the bladder-cells connected with the superior nucleus of the trigeminal.

The second gray zone seems to partake of the structure of the formatio reticularis and contains scattered nuclei and is bounded peripherally by a discontinuous zone of fibres, apparently extending obliquely caudad. In connection with these fibres are numerous large multipolar cells, whose processes can be traced in various directions, especially peripherad, for long distances. The space intervening between this tract and the tract formed by the fibres from the optic tract is a reticulum of fibres and cells in concentric and radiating chains. A few of the large multipolar cells are likewise sparsely scattered through

it. The remaining zone of gray is the cortex, and is connected by fibre and cell chains with at least the two median layers.

In just what way the cortex is related to the optic tract is difficult to determine. In some places there is still a superficial fibre tract corresponding to the stratum zonale. The outer layer of the nates contains, as already said, radiating systems of fibres and cells. Of the latter four kinds are recognized. First, a system of superficial pyramidal cells, with their bases peripheral, each with a single process passing toward the center. These cells measure .017–.02 mm., with a nucleus .006 mm. in diameter. The protoplasm stains very faintly and the cell gives off a process which may unite with cells of the fourth sort. It must be left at present undetermined whether these cells are really nervous or not. We could not be certain that basal processes connect them with the superficial fibre zone. Second, very numerous nutritive cells of the usual type are scattered irregularly. Third, nucleated cells of the walls of the blood vessels differentiate strongly. Fourth, elongate, bipolar, fusiform cells, .013 mm. long by .003 mm. wide. Below these, and apparently connected with them, are much larger cells of somewhat pyramidal form, with a single peripheral process, blunt proximal extremity with several processes, and a large nucleus. These cells measure .024–.027 mm. in length by .01–.013 mm. in width. Fig. 6, Plate XIX, is a semi-diagramatic illustration of the cells of the superficial layer, as seen in longitudinal section (VII-*e*-2) under the one-fifth inch objective.

(Consult in this connection *Tartuferi*, Sull' Anat. Minut. dell' Eminenze Bigem., etc., in Revista Sperimentale, 1879, *Ganser*, Die periph. u. cent. Anordnung d. Schnervenpaare u. d. Corpus Bigem. Ant., Archiv. f. Psychiatrie, Bd. XIII., *Nonakow*, Die Beziehung d. sogenannt. Sehsphaere z. d. infracorticalen Opticuscentren, etc. ibid, Bd. XIV, and *Belloncí*, Ueber d. centrale Endigung des Nervus Opticus bei d. Vertebraten. Zeitsch. f. w. Zool., Bd. XLVII.)

At the medio-ventral aspect of the sections which display the entrance of the third nerve roots, Meynert's bundle has assumed the longitudinal direction, forming a transversely-cut tract between the roots of which there are over one dozen bundles on either side. In sections farther caudad than Fig. 1, Plate IX, the ventricle of the optic lobes vanishes without divaricating. The non-appearance of the colliculi, as seen in lower vertebrates, is to be explained as due to this fact, *i. e.*, the substance of the colliculi fused with the sub-natal gray

matter. At this level, too, the tracts from Meynert's bundle apparently enter a small, dense interpeduncular nucleus between the third nerve roots and somewhat caudad to them. A large nucleus, (Steida's *nucleus peduncularis*,) laterad to the third root tracts, and another near the median line, *nucleus interpeduncularis*, to which the fibres of Meynert's bundle can be directly traced, are also visible (Fig. 3, Plate IX.) Compare Plate X, Fig. 1.

Longitudinal vertical sections through the corpora quadrigemina at the locus of the third root, are especially instructive as to the relations existing between the third, fourth and other nuclei. (Plate X, Fig. 1.) The figure sufficiently illustrates the chief peculiarities. The nucleus of the third lies chiefly below and laterad from the strong median ascending tract and is largely involved in its fibres. The fourth nuclei are composed of entirely similar cells lying in a group caudad and dorsad to the previous nuclei and lying above the ascending tract and near the sides of the floor of the aqueduct. The tracts of IV are seen as two or three circular sections (tr. IV.)

The descending fibres of what is apparently Meynert's bundle can be traced to a point near the entrance of the third nerve. A strong bundle (tr.) from the prominence immediately in front of the outer passes obliquely caudad and mesiad.

The third nerve arises by a number of very small roots which subdivide on entering the substance of the pes into still smaller strands. The course of the fibres can be easily followed dorsally and caudad to a considerable nucleus a little ventrad from the aqueduct. In transverse section the outline of this nucleus is triangular and consists of two indistinctly separated portions, a smaller (dorsal) portion and a larger ventral mass, from the base of which the fibres radiate ventrad to the tracts through a white zone surrounding it. The centre of the nucleus lies dorsal to the anterior edge of the pons.

Ventrally and a little laterad is the larger nucleus, the cells of which are in some respects similar, but average rather larger, (Plate IX, Fig. 3, *n*2) but from it no fibres can be traced to the tracts of III which latter, in converging toward the nucleus proper at the median line, in part pass through the substance of this cluster. This *peduncular nucleus* is remarkable in that its cells are exceedingly irregular and wrapped about the strands of the longitudinal tract. These many-branched cells lie in angles of decussating fibres, and like similar cells of the ventral cornua of the cord, send off fibres to the several tracts.

Of these tracts especially well marked is a bundle of arching fibres passing from this nucleus dorsally toward the nates but apparently converging over the aqueduct to the posterior commissure. It may be suggested that this nucleus is centre of co-ordination for the oculomuscular aparatus.

The region of the third ventricle.

Horizontal sections through the lowest portion of the tuber cinereum reveal the same structure as described in the tuber of the alligator, *i. e.*, a dense layer of epithelium lining the ventricle, the cells of which give rise to long fibres of connective tissue dividing the space about the ventricle into compartments in which the very numerous flask-shaped cells are closely packed. The entire tuber is filled with these cells. At its posterior portion are two more densely nucleated spots laterad to the lowest point of the fornix tract.

In higher sections the above-mentioned nuclei and the cephalad and caudad parts of the fornix tracts become quite distinct. The nuclei above described, which may be called the posterior nuclei of the tuber, give rise to fibre tracts passing dorsad and cephalad laterally from the cephalad tract of the fornix. About the sides of the third ventricle, cephalad is a large, dense nucleus of small cells, the anterior tuber nucleus, and in front of this on either side, not far caudad of the chiasm, is a small tract in cross section. This small bundle can be traced dorsad for some distance, but its ultimate course is unknown.

The structure about the third ventricle remains quite constant but cephalad from the lamina terminalis is a nucleus of spider-like, slender multipolar cells with remarkably long and distinct processes passing in all directions through a coarse reticulum of fibres (VII *b* 15). Both divisions of the fornix tract lose their distinct contours before the level of the anterior commissure is reached, the caudad tract, especially, fuses with the gray matter of the thalamus. The cephalad portion emerges immediately caudad to the commissure. Meynert's bundle at this level is some distance cephalad to the oculomotor tracts.

Three more or less distinct masses of gray matter appear in the lateral aspect, the middle one being the largest and most densely nucleated and being recognized as the corpus geniculatum.

The most remarkable nucleus remaining is the ganglion of the superior commissure or nucleus of the habenulæ. This is a compact

dense nucleus of paraxial multipolar cells greatly resembling in size and form the cells of the third and fourth nuclei. This nucleus is situated in the latero-cephalad portion of the thalamus behind the commissure of the hippocampus. It is related to the epiphysis dorsally and a strong ventral bundle (tænia thalami) medianly. The whole dorso-cephalad part of the thalamus is thickly sown with cells, especially medianly, while a dense clustre of cells of the same sort is situated near the median line a short distance cephalad of the posterior commissure. The axial direction of the last mentioned cells is vertical and they give rise to the fibres of Meynert's bundle. The nucleus may be termed nucleus of Meynert's fasciculus.

The ascending fascicle of the fornix after meeting the anterior commissure passes dorsad to it, entering the septum and becoming enveloped in cubical gray masses lying between the corpus callosum cephalad and the commissure of the hippocampus caudad. The gray mass contains numerous small nuclei. Gradually this mass (and with it the fornix fibres) fuse with the hippocampal commissure.

The strong tract descending from the habenulæ passes laterally and disappears in the region of the peduncular tracts and can be traced no further.

Comparative data from Didelphys.

The following memoranda are derived from a series of sections from the opossum. Two principal bundles emerge from near the ventral surface of the medulla, anteriorly. The median pair bound the trigonum and are laterad to the small oculomotor nerve roots. These ventral pyramids of the peduncles pass obliquely cephalad and laterad to a point caudad to the chiasm, where they turn abruptly dorsad.

The laterad pair of bundles pass obliquely dorsad from the latero-cephalad aspect of the medulla to the caudad aspect of the mesencephalon.

The second or sensory bundle continues in its dorsal course as a semicircular, and finally a circular bundle, to the horizontal plane including the summit of the anterior commissure; there it begins to break up until, at the level of the corpus callosum and hippocampal commissure, it becomes a reticular formation beneath the testes. The further course of these fibres is obscure, but it appears that they are continued cephadal through the thalamus and take part in the decussation of the an-

terior commissure. This commissure, which is so large relatively as to take the place of the corpus callosum of higher mammals, gathers fibres from the entire ventral and occipital region and appears to contain not only decussating fibres, but a large number of co-ordinating strands. The connection with the olfactory lobes is evident and direct.

The pyramidal tracts cross the anterior commissure laterally and form almost immediately a number of separate bundles passing directly dorsad. They may be traced chiefly to the antero-dorsal cortex, though smaller bundles pass caudad and a few isolated fibre tracts from this tract seem to reach the ventro-lateral regions.

Numerous small bundles decussate in the ventral part of the crural region.

The course of the fornix seems to be identical with that of the rodents.

A strong tract from the habenulæ follows nearly the same course already described for Arctomys, but the ganglion occupies the very summit of the thalamus, while the ganglion of Meynert's fasciculus occupies the median aspects of the upper part of the third ventricle. The superior commissure is a very short distance cephalad and dorsad from the posterior commissure and its fibres can be readily traced to the ganglion habenulæ. A tract passing from the testes to the cerebellum was provisionally recognized.

We have already intimated that the received statements regarding the absence of the corpus callosum are only apparently true. The microscope reveals the presence of a commissure in the proper position to receive this name. It is a small fibre bundle dorsad and cephalad to the commissure of the hippocampus and is a true cortex commissure. It is not larger relatively than the corresponding bundle in the alligator or turtle and therefore does not impeach the validity of the argument against the common origin of marsupials and other mammals. Other details are reserved for an article now under way.

Details of successive transverse sections through the thalamus and corpora striata.

(VI *a*-19.) Section cephalad from the corpus callosum.

At this level the whole dorsal and outer, as well as dorso-median, cortex is similar and the fibres of the white matter converge toward the striatum. Two sets of fibres may be distinguished, the one passing toward the lateral aspects of the corpora striata, the other being

the commissure. The cortex is about 2 mm. deep and the white fibre layer below is one half as thick. The fibres from any given region gradually accumulate in bundles adjacent to the corpus striatum and finally perforate it obliquely. Here they pursue an oblique ventral course and tend to accumulate in still larger bundles. The larger bundles are in the dorsal part of the striatum, the whole substance of which is filled with small fusiform or flask cells of uniform size and irregular direction. The form of the striatum is here irregularly quadrangular. Besides the fibres radiating to the corpus striatum, the white matter beneath the cortex contains an approximately equal number, which obviously are converging to the corpus callosum. These fibres or rather similar fibres from cephalad parts of the hemisphere collect above the ventricle (by it separated from the striatum) to form the callosal tract, which is separated from the median fissure by a thin septum lucidum. The septum is here crowded with fusiform cells and is separated from the cortex proper by the calloso-marginal fissure. Between the septum and the corpus striatum, ventrad from the callosal tract, is a ganglionic mass like the striatum in its cell structure, but free from fibre tracts and separated from the septum by a poorly aggregated tract. This mass is associated with the body of the fornix.

Below the corpus striatum is the central olfactory tract, which consists of two portions, and is very distinct from everything about it.

The entire ventral portion (or pyriform lobe) is peculiar in the absence of any orderly arranged cortical gray. On the other hand, its cells are aggregated in small, dense clusters or sinuous masses and a little distance within the cortex is a greater number of small, disperse fibre tracts which appear to be derived from the superficial olfactory tract, which latter here occupies the latero-ventral aspect.

(VI*a*, 21.) In sections near the the front of the callosum the ventricle has extended ventrally and severed the non-fibrous median gray or fornix nucleus, making of it an intraventricular aggregate, the medio-ventral part of the septum lucidum remaining distinct from it. In sections further caudad the tracts near the ventral surface have retreated dorsad and collected near the olfactory tract. The tract from the ventral part of the septum has descended toward the ventral region and dense clusters of large fusiform cells gather in its medio-ventral portion.

Gradually the intra-ventricular gray matter (fornix body) assumes a quadrate section, the central olfactory tract begins to reach a median

position, and the superficial one spreads over the whole pyriform lobe.

The next section (Fig. 8, Plate II,) taken behind the chiasm shows the optic tracts collected on either side of the now distinct thalamus and separated by the infundibulum. The olfactory tract crosses the narrow third ventricle by a sudden curvature via the anterior commissure which seems to be a genuine commissure of the olfactory and adjacent sensory tracts.

An important tract now first appears. It consists of fibres passing obliquely dorsad behind and ventrad to the commissure. Neither upper nor ventral terminus appears in this section, but the fibres can be traced ventro-laterad and caudad to form the descending tracts of the fornix, as already seen in longitudinal sections, and cephalad and dorsad until they unite the so called fornix nuclei of both sides by a strong decussational band near the ventro-caudad border of the callosum. We can not determine whether there is absolute continuity between all these fibres and the commissure of the hippocampus. The latter is certainly chiefly made up of the fibres from the fornix, but it also appears that some of the fibres from the hippocampus are truly commissural while, on the other hand, some at least of the fornix fibres appear to terminate in the gray matter of the fornix nucleus or body.

The farther course of the descending tract of the fornix has been given above. We do not find evidence of the absolute continuity of the fibres of this tract with those of the fasciculus of Vicq d'Azyr or ascending fornix tract of Ferrier.

The body or nucleus of the fornix adheres to the inferior surface of the corpus callosum, but there is no evidence of organic connection.

Plate I, Fig. 8, illustrates a section near the front of the corpus callosum. The fornix body has already become distinct from the corpus striatum. The central tract of the olfactory nerve lies ventrad and slightly dorsad from the line *e*, the external tract being near *b*.

Plate II, Fig. 8, represents a section at the anterior commissure. The prominences of the fornix body are here quadrangular and medianly give rise to tracts which pass caudad to the commissure. The optic tract appears near the median line above 1. Plate IV, Fig. 1, exhibits the relations of the tracts descending from the fornix nucleus. In sections immediately following, a very broad band of fibres connects these two prominences and their extension also unites the ventral surfaces of the hippocampus. This belt of fibres has suffered the same involution that the substance of the hippocampus has, and in

consequence has been rolled into a band with a semicircular section, so that a section further back (Plate IV, Fig. 2,) reveals the fornix fibres dorsally attached to the hippocampus. This throws needed light upon the fornix, hippocampus, and their relations. The hippocampus is essentially the whole caudad margin of the cortex which by continued peripheral increase has rolled itself in the longitudinal direction and at the same time arched about the peduncles as they converge from the striatum toward the sides of the thalamus. This passage of the peduncular fibres can be well seen in sections somewhat cephalad to Fig. 1, Plate V, and in Plate V, Fig. 2, where the peduncular fibres have already crossed and lie mesiad from the optic tract which forms the lateral wall of the thalamus. Near the lower ventral and median extremity one may detect the remnant of the fornix tract on its way to the mammillary body. Laterally, the ragged portion of gray matter projecting into the ventricle is the remnant of the striatum after the crossing of the fibres to the thalamus.

Returning to the hippocampus, its fibres pursue as nearly as possible the usual course, *i. e.*, part pass directly across, forming the commissural part of the fornix, and other fibres descend in the body of the fornix to the body of the thalamus and thence to appropriate nuclei in that organ.

In the region of the anterior commissure, a number of the ventral bundles of fibres, which may be regarded with a high degree of probability as sensory in function, now begin to cross to the thalamus, meanwhile the dorsal bundles which occupy the striatum proper become constantly more compact. The principal sensory bundles seem to be driven medianly until the sides of the thalamus are occupied by a rather compact motor column. The relations described are well shown in Figs. 1 and 2, of Plate V. Fig. 2 also shows the fornix fibres near the mammillary body.

The olfactory tracts are somewhat difficult to follow. Two of them are distinct and may be traced to the same general region of the hemispheres and thalamus. The inner tract passes directly backward from the centre of the crus olfactorius (Plate II, Fig. 1,) to beyond the anterior cornu of the ventricle, where it seems to divide, sending a branch to the superficial tract. Thence it may be traced backward in successive transverse sections to the region of the anterior commissure. (In Fig. 8, Plate I, the olfactory tract lies a little above and to the left of the point indicated by *c.*)

The superficial tract of the olfactory fibres passes along the ventral surface in ill-defined bundles to the hippocampal region. Here small, dark, angular, multipolar cells abound, similar to those of the anterior or fornix eminentia of the thalamus. The relation of the hippocampus with the fornix has already been indicated. It is probable that fibres from the hippocampus pass to the higher cortical regions via the fornix commissure, just as in the reptilia. It is not impossible that there is a connection of the central tract with the hippocampus, but such a communication was not demonstrated.

Other fibres seem to depart from the main tracts and gather at the anterior commissure. The anterior commissure in the brain of the rat was studied for comparison with the result of confirming the suggestions already made.

The transverse sections have thrown no light on the course of the fibres from the dorsal nucleus of the thalamus (*taena thalami*), which in horizontal sections are found to pass ventrad along the cephalic border of the thalamus, behind the callosum and anterior commissure, to the point of entrance of the pyramidal fibres into the hemisphere. We think it probable that these fibres make their way to the hippocampal or occipital region of the cortex.

The Prosencephalon.

(It will be convenient in presenting the few notes we at present offer upon the fore-brain, to reverse the order hitherto followed.)

(*a.*) The *olfactory lobes* are of considerable size and are connected with the cerebral hemispheres by a relatively thick crus olfactorius. The form of the bulb proper is ovoid and it is obliquely appressed upon the front of the hemisphere.

Microscopically the structure is not unlike that of the human subject. The outermost layer consists of bundles of olfactory nerves passing in various directions to unite with the glomerular layer. The exact method of emergence was not observed. The so-called glomerular layer is simply a belt of fibre bundles, each bundle being surrounded by a cluster of "neurilema nuclei." The olfactory fibres are more or less convoluted and are separated by a dense reticulum of neuroglia. The glomerular layer insensibly passes into the more homogeneous but otherwise similar gelatinous layer. Here the olfactory fibres pass through a dense net-work of connective tissue with sparse neuroglia nuclei. Forming the inner boundary of the gelatinous layer

is a layer of ganglion cells. These cells are pyramidal and give off three or more acute projections peripherally, but extend into a thick axillary process below. The number of ganglion cells is relatively very small. The bases of these ganglion cells are immersed in a dense zone of neuroglia nuclei, which are oval and furnished with very prominent nucleoli, one always being central, they are not more than one-fifth the length of the ganglion cells, and their function may be to nourish the ganglion cells and insulating layer of the centripital nervous processes. The following layer is composed of nerve fibres, which are collected in bundles closely invested by nuclei similar to those above described and divided into upper and lower tracts by the olfactory ventricle. The dorsal part of the crus olfactorius has a cortical layer, differing materially from that of adjacent parts of the cerebrum.

The course of the fibres is difficult to trace in detail. There are two distinct tracts, the upper passing directly to a point below ventral point of the lateral ventricle, partly mingling with the cortical fibres of that region and passing through the base of the corpus striatum, but giving off a branch which unites with the lower superficial tract which passes obliquely backward upon the surface to what has been called the pyriform lobe.

Fig. 9, Plate I. Transverse section of olfactory lobe. (a,) granular layer, (b,) gelatinous layer, (c,) position of ventricle, (d,) ganglion layer, (g.) glomerular layer, (f,) fibre tracts.

Fig. 1, Plate II. Longitudinal section of anterior part of hemisphere and olfactory lobe. Fig. 1*a*, fibre bundle, enlarged. Fig. 3, Plate II, section through ganglion and adjacent layers. much enlarged. Fig. 2, Plate II, portion of cortex at base of crus olfactorius.

[Note.]—Althongh most of the time devoted to this paper has been employed in the study of the histology, especially of the cortex, his section must be omitted till the next issue, because of vexatious delays.

EXPLANATION OF PLATES.

The sections are all drawn, unless otherwise stated, by means of the camera lucida.

PLATE I.

C. L. Herrick.

Transverse sections of the right hemisphere of Arctomys to a uniform scale.

Fig. 1. Cross-section of olfactory bulb. *Cf.* Fig. 9.

Fig. 2. Cross-section of hemisphere and crus olfactorius.

Fig. 3. Cross-section of hemisphere at the junction of the crus olfactorius.

Figs. 4–8. Sections taken at frequent intervals across the hemisphere, extending as far caudad as the corpus callosum.

Fig. 9. Enlarged section of the lobus olfactorius. Compare also Plate II, Figs. 1–4.

Fig. 10. Portion of Fig. 9, enlarged.

Fig. 11. Frontal cross-section of the right hemisphere and corpora quadrigemia of the rat, for comparison with sections figured on Plate V.

Fig. 12. Cells from cortex of crus olfactorius at point indicated by *b*, Fig. 4, (.025 mm. long.)

Fig. 13. Small area from cortex of ventral surface of hemisphere, in sections passing through the front of the callosum. (*C.* Fig. 8,) x 170.

Fig. 14. Portion of cortex from ventral aspect of hemisphere, near median portion of the pyriform lobe at the level of the anterior commissure. (Fig. 8 *a*, Plate II.)

PLATE II.

C. L. Herrick.

Fig. 1. Longitudinal vertical section of anterior portion of hemisphere of Rabbit.

Fig. 1*a*. Portion of glomerular layer of olfactory nerve bundle.

Fig. 2. Portion of upper cellular layer of crus olfactorius.

Fig. 3. Section through the granular, ganglionic, and gelatinous layers of olfactory lobe.

Fig. 4. Horizontal section of anterior part of cerebrum, with olfactory lobe, *Arctomys*.

Figs. 5–7. Similar sections at successively higher levels as far as to the corpus callosum.

Fig. 8. Transverse section through the corpus callosum and anterior commissure.

Fig. 9. Section of part of fornix body.

Fig. 10. (III*c*–13.) Horizontal longitudinal section through the middle of the right hemisphere, passing through the corpus callosum and the hippocampal involution.

PLATE III.

C. L. Herrick.

Details from sections of preeeeding plates.

Fig. 1. Portion of corpus striatum, x 25.

Fig. 2. Cortex near olfactory tract in transverse section at cephalic margin of corpus callosum.

Fig. 3. Portion of cortex near middle of median fissure in transverse section, half way from front to corpus callosum, x 165. The arrow indicates the direction of the surface. Two sorts of cells, centrifugal preponderating.

Fig. 4. Typical motor area. (VI*a*–24*a*) Giant or ganglion celllayer near median fissure. (Compare Fig. 7.) x 165.

Fig. 5. Similar motor area in VI*a*–7, in front of the corpus callosum, in about the middle of the superior surface. Only the upper layers. x 165.

Fig. 6. Deep layer of cortex of median fissure near the lower third of vertical diameter. x 165.

Fig. 7. Section entirely through the cortex of VI*a*–24, at same point as Fig. 4. x 86.

PLATE IV.

C. L. Herrick.

Fig. 1 Transverse section through the hemisphere near the middle of the corpus callossum, showing the position of the fornix body and descending tract of the fornix. Also the relations of the corpus striatum and optic tracts.

Fig. 2. Transverse section through the thalamus, to show the relation of the hippocampus, its commissure and the rearrangement of the white matter in the thalamus. A small fragment of the corpus striatum remains.

Fig. 3 Portion of *a*, Fig. 2, enlarged. Structure of the hippocampus.

Fig. 4. Portion of cortex along median sulcus, (*d*, Fig. 2.)

Fig. 5. Small area from thalamus at *c*, Fig. 2.

Fig. 6. Deeper part of lateral cortex, (Fig. 2*b*.) The cells apparently flask-shaped, with the acute apical process median. Is this due to oblique section of pyramidal cells?

PLATE V.

C. L. Herrick.

Fig. 1. Section somewhat cephalad from Plate IV, Fig. 2. The crossing of fibres from the paries of the thalamus to the hemisphere, is shown.

Fig. 2. Transverse section farther caudad, showing adhesion of the hippocampus with the corpus callosum, also the position of the descending fornix fibres near the medio-ventral portion.

Fig. 3. Transverse section of hemisphere at the caudad extremity of the hippocampus.

Fig. 4. The entire brain seen from the dorsal aspect. For results of electrical stimulation see page 38.

Fig. 5. The same viewed from the ventral aspect.

Fig. 6. Another brain dissected and laid open to display the corpora quadrigemina, thalamus, ventricles, etc.

PLATE VI.

C. L. Herrick.

This plate illustrates the distribution and arrangement of the cellular elements in the postero-median areas of the cortex.

Fig. 1. (III*c*–12*a*) Giant or ganglion cells from a transverse section of the right hemisphere near the posterior part of dorsal surface and near the middle of transverse diameter. Chiefly centrifugal cells; a few centripetal. Camera. Magnified about 165 diameters.

Fig. 2. (VI*b*–15*e*.) Portion of transverse section in front of infundibulum at a point about 5 mm. from median line, giant or ganglion cells from the area governing sphincter of eye-lids. Camera, x 165.

Fig. 3. (VI*b*–15*f*.) Cells from the same section and depth, but farther from the median line and hence in the sensory area. Camera, x 165.

Flg. 4. (VI*d*–6*a*) Portion from transverse section in advance of Fig. 1. showing the upper part of the cortex in the sensory area. The section appears to be a little in advance of exit of oculo-motor roots. Camera, x 165.

Fig. 5. (VI*b*–3*a*.) From a transverse section a little back of the chiasm. Extreme lower part of the lateral surface of cortex, near the sulcus and occupying same relative position as (VI–15*b*,) multipolar and centripetal cells of middle zone of cortex.

Fig. 6. (III*d*–16.) Section near the chiasm. Camera, x 165. Giant cells of motor area, x 250, 1-10 inch objective and camera.

Fig. 7. Opossum, at juncture of fibre layer and cortex, near median fissure, half way from crucial sulcus to front. Section longitudinal.

Fig. 8. (V*b*–7*a*.) Radial longitudinal section taken with corpus quadrigeminum as a centre passing through a point midway between median fissure and

base of hemisphere, 2-3 mm. posterior to chiasm. Rabbit. Chiefly centripetal cells.

Fig. 9. (VI*b*-17*a*.) From a transverse section a short distance posterior to infundibulum. The portion figured lies about 12 mm. from the median line and extends from the white matter upward through the ganglionic layer.

Fig. 10. (VI*b*–20*a*.) Still further back near the middle of the exposed part of the cortex. The portion figured supplements Fig. 9, covering the upper part of the cortex to below the giant cells. Drawn to a scale without camera. A mixture of centripetal and centrifugal cells. (See Plate VII, Fig. 1*a*. From nearly the same area as Plate VII, Fig. 2.)

PLATE VII.

C. L. Herrick.

Fig. 1. Section through infundibulum shaded to indicate the distribution of centrifugal cells in the cortex. Cephalic surface of a section of right hemisphere.

Fig. 2. (VI*b*–20*a*.) Porion of a section through the pyriform lobe, exhibiting the centripetal variety of cells unmixed with centrifugal. At the lower curvature, however, both varieties occur. x about 165.

Fig. 3. Portion of the same section near the middle of the arc of the upper surface in an area where both varieties of cells are commingled.

Fig. 4. Opossum. Section through entire cortex and hippocampus. transverse section in front of the anterior commissure. Six layers. I. Neuroglia layer. II First nucleary zone, cells about .03 long, in the upper part fusiform, below pyramidal. III, First granulary layer. IV. Giant cells .04–.045 long. V. Imperfect second granular layer. VI. Transition zone. VII. Fiber zone. (Slide 19.)

Fig. 5. Opossum. Section through hippocampus. (No. 33.)

Fig. 6. Opossum. 5 mm. in front of crucial sulcus and a little nearer the median side than the external. Deep layer of cells.

Fig. 7. Opossum. Slide 22. Deep cortical layer toward lateral ¼ of superior surface. Corresponding to layer 4, of Fig. 4. Giant cells. Section transverse and just in anterior part of anterior commissure. Cells about .04 mm. long.

Fig. 8. Opossum. Slide 79. Longitudinal section near middle of hemisphere, half way between crucial sulcus and front giant cell layer.

PLATE VIII.

C. L. Herrick.

Fig. 1. Section through one-half the thalamus just back of the infundibulum.

Fig. 2. Similar section through the anterior part of corpus quadrigeminum a very short distance back of the preceeding.

Fig. 3. Similar section a few hundredths of a millimeter farther caudad.
Fig. 4. Portion of Fig. 1, enlarged. x 165.
Figs. 5-9. Portions of Fig. 2, enlarged. x 165.
Fig. 10. Portion of Fig. 4, enlarged. x 165.

PLATE IX.

C. L. Herrick.

Fig. 1. Transverse section through the anterior corpus quadrigeminum, at the point of the 4th (oculo-motor) nerve. *Ot.* Optic tract fibres. *As.* Aqueduct of Sylvius. *Pp.* Pes pedunculi. *R.* Roots of nerve IV.

Fig. 2. Section somewhat farther back. *Rph.* Raphe. *L.* Lemniscus fibres.

Fig. 3. Section still further back, near the middle of the corpora quadrigemina.

Fig. 4. Section still farther back at the anterior margin of the pons.

Fig. 5. Section at the caudad margin of corpus quadrigeminum anterior.

Figs. 6-7. Transverse sections of corpus striatum in sections lying between Fig. 6, and Fig. 7, of Plate I. More highly enlarged.

PLATE X.

C. L. Herrick.

Fig. 1. Longitudinal vertical section through the corpora quadrigemina, somewhat laterad from the ventricle. *tr.* Tract from the posterior commissure. *IV.* Root of the trochlearsis. *tr, IV.* Tract of the trochlearis near its nucleus, *n. IV.* *n. III.* The principal portion of the nucleus of the oculo-motor. *III.* Root of the oculo-motor. *Mb.* Meynert's bundle Inferiorly, a portion of the pons is shown, while superiorly, the nates and testes are cut nearly medianly.

Fig. 2. Upper portion of the nucleus of the third nerve of the left side, (VI *c*–15.)

Fig. 3. Lower portion of nucleus of third nerve.

Fig. 4. Nucleus of the trochlearis.

Fig. 5. Median portion of the right hemisphere of *Lepus Sylvaticus*, to indicate especially the position of hippocampal commissure. The section is somewhat oblique, *i. e.*, inclined from right ventral toward the left.

Fig. 6. Section of the medulla and cerebellum of the left side at the exit of the root of the facialis and abducens.

Fig. 7. Portion of transverse section of posterior median portion of hemispheres of *Blarina brevicauda*, short-tailed shrew, especially for the relations of the hippocampus and corpus callosum.

PLATE XI.

C. L. Herrick.

The figures of this plate are chiefly intended to facilitate a comparison of the brain of Arctomys with other animals.

Fig. 1. Median longitudinal section of the brain of a young raccoon, *Procyon lotor.* The interrupted character of the calloso-marginal convolution along its margin and the highly convoluted limbic region are noteworthy. The primitive condition seen in the lack of a curvature in the brain axis is more than compensated for by the backward projection of the cerebrum, nearly covering the compact and closely convoluted cerebellum. The relations of the scarcely arched corpus callosum, fornix, anterior commissure, thalamus, pineal body, and mesencephalon, are well shown in the figure.

Fig. 2. Dorsal surface of a raccoon of the same age. The figures indicate positions stimulated by the electric current as described in the text.

Fig. 3. Ventral surface of another specimen of the same age, somewhat shorter than when in natural relations. The peculiar relations of the olfactory and optic tracts are noteworthy. The mammillary bodies and the plainly indicated tracts of the medulla may also be noted. The position of the third, fifth, seventh, and eighth roots alone is indicated.

Fig. 4. Dorsal surface of cerebrum of adult raccoon. somewhat shrunken and distorted.

Fig. 5. Dorsal surface of cerebrum of a quarter grown pup. *x*, indicates a lesion resulting in slight motor disturbance of the hind leg of the opposite side.

Fig. 6. Ventral surface of the brain of a kitten. With eyes still closed.

Fig, 7. Dorsal view of the same brain.

Figs. 8-11. Transverse sections of the cerebrum of the raccoon. Fig. 9, 22 mm. back of anterior margin. Fig. 10, 36 mm. back of anterior margin and just back of the chiasm.

Fig. 11. Still near the posterior or occipital margin of the hemispheres.

Figs. 12-14. Sections of the brain of the rabbit, *Lepus sylvaticus.* Fig. 12. View of corpora quadrigemina and left hemisphere from behind.

Fig. 13. Section at the middle region, and

Fig. 14. Near the anterior of the hemispheres.

Figs. 15-17. Cellular structure of the brain of the oppossum, *Didelphys.* Fig. 15. Portion of the cortex in front of crucial sulcus near the median line. Fig. 16. Cells from the hippocampal region. Fig. 17. An instance of anastamosis of co ordinate motor pyramids.

Figs. 8 19. Ventral and lateral views of brain of adult opossum.

Fig. 20. Transverse section of same brain at anterior commissure.

PLATE XII.

C. L. Herrick.

Fig. 1. Horizontal section of left hemisphere and thalamus behind the corpus

callosum, where the peduncular fibres cross to the thalamus.

Fig. 2. Cells from the area marked 11, in Fig. 6.

Fig. 3. Cells from the hippocampal region of the ground hog, the ventricle being at the right, the transition into the hippocampus at the left, to show the two varieties of cells at the ventro-caudad part of the posterior cornu.

Fig. 4. Cells from the fornix body, corresponding to *b*, Fig. 8, Plate II. The cells are .021 mm. long.

Fig. 5. Brain of a second individual of *Arctomys* for comparison with Fig. 4, Plate V. One-half size.

Fig. 6. Transverse section of brain of a kitten, at the hippocampal commissure.

Fig. 7. Section of the cortex at 2, in the preceeding figure.

Fig. 8. Portions of the superficial, middle and deeper parts of the cortex, adjacent to the corpus callosum in the lobe marked 1, in Fig. 6.

PLATE XIII.

W. G. Tight.

Fig. 1. A transverse section of the cervical region at the entrance of the second dorsal nerve root.

a. Nucleus of ventral cornu.

b. Neck of dorsal cornu.

c. Ventral median column.

d. Spinal accessory nerve.

e. Canalis centralis.

f. Ventral commissure.

g. Burdack's column.

h. Goll's column.

Fig. 2. A magnified view of the cells from the cervix of the dorsal cornu, Fig. 1, *b*.

Fig. 3. A magnified view of the motor cells of the ventral cornu, Fig. 1, *a*.

Fig. 4. A transverse section of the cervical region of the cord at the entrance of the first dorsal and exit of first ventral nerve roots.

a. Cervix of dorsal cornu.

b. Ventral cornu nucleus.

c. Ventro-lateral cell-group of ventral cornu.

d. Median aggregation of cells.

Fig. 5, Magnified view of cells from neck of dorsal cornu, Fig. 4, *a*.

Fig. 6. Magnified view of ventral median column of cross section of nerve fibres.

Fig. 7. Magnified view of cross section of nerve fibres from Goll's column, Fig. 1, *D*.

Fig. 8. Magnified view of cells from ventral cornu nucleus, Fig. 4, *b*.

Fig. 9. Magnified view of cells from the ventro-lateral cell group of ventral cornu. Fig. 4, *c*.

PLATE XIV.

W. G. Tight.

Fig. 1. A transverse section of medulla at the first appearance of the decussation.

a. Entrance of small bundle of XIth nerve root.

b. Nucleus of ventral cornu.

c. Nucleus of dorsal cornu cervix, elevated.

d. Median nucleus.

e. Commencement of ventro-dorsal lateral nucleus.

Fig. 2. Magnified section of the olivary body *a*, as seen in Fig. 6, Plate XIV, *a*.

Fig. 3. Magnified view of a portion of *c*, Fig. 5, Plate XIV.

Fig. 4. Magnified view of *e*, Fig. 6, Plate XIV.

Fig. 5. Cross section of medulla at the decussation, just caudad to the olivary body.

a. Decussation.

b. Median nucleus.

c. Ventro-dorsal lateral nucleus.

d. Funiculus gracilis.

Fig. 6. Cross section of the medulla at the central part of the deccussation.

a. Olivary body.

b. Ventro-dorsal lateral nucleus.

c. Decussation.

d. Ventral portion of the median nucleus, nucleus of the XIIth nerve.

e. Dorsal portion of the median nucleus, nucleus of XIth nerve.

f. Funiculus gracilis.

PLATE XV.

W. G. Tight.

Fig. 1. Cross section of medulla at the entrance of the XIIth nerve root.

a. Nucleus of Xth.

b. Nucleus of XIIth.

c. Cuneate nucleus.

d. Portion of the formatio reticularis.

e. Nucleus of the raphe.

f. Entrance of the XIIth nerve root.

g. Olivary body.

h. Tubercle of Rolando.

i. Nucleus laterale.

k. Pyramid.

l. Restiform tract.

Fig. 2. Magnified view of Fig. 1, *a*, nucleus of Xth nerve.

Fig. 3. Magnified view of Fig. 1, *e*, raphe.

Fig. 4. Magnified view of Fig 1, *d*, formatio reticularis.

Fig. 5. Magnified view of Fig. 1, *b*, nucleus of XIIth nerve.

Fig. 6. Magnified view of Fig. 1, *c*, a portion of cuneate nucleus.

PLATE XVI.

W. G. Tight.

Fig 1. Transverse section of the medulla at the entrance of a small bundle of the Xth nerve.

a. Entrance of the Xth nerve.

b. Nucleus of the Xth nerve.

c, Nucleus of the XIIth nerve.

d. Olivary body.

e. Pyramid.

f. Ventro-lateral nucleus.

g. Restiform body.

h. Raphe.

Fig. 2. Transverse section taken at the entrance of some fibres of the nerve IXth, root and first fibres of VIIIth nerve.

a. Nucleus of IXth nerve.

b. Nucleus of VIIth nerve.

c. Inner portion of VIIIth nucleus.

d. Restiform Body.

e. Internal reticular nucleus.

f. Pyramid.

g. Fibres from the VIIIth root.

h. Dorsal longitudinal bundles.

Fig. 3. A transverse section of the medulla at the entrance of the auditory (VIIIth) nerve.

a. Nucleus of the VIIth nerve.

b. Deiter's nucleus in the peduncle of the cerebellum.

c. Nucleus of root of VIIIth nerve.

d. Interior of VIII nucleus.

e. Nucleus of the raphe.

f. Restiform body.

g. Pyramid.

h. Dorsal longitudinal bundles.

i. Entrance of VIIIth nerve.

Fig. 4. Magnified view of (VI–*e*–1*a*), multipolar cells of the nucleus of the VIIth nerve.

Fig. 5. Magnified view of cells from Deiter's nucleus.

Fig. 6. A longitudinal section of the medulla taken parallel to the base at the level of the Vth and VIIIth nerves.

a. Entrance of the VIIIth nerve.

b. Nucleus of root VIIIth nerve.
c. Root of Vth nerve.
d. Nucleus of Vth nerve.
e. Openings left by the removal of the fibre bundles of VI and VII.

PLATE XVII.

W. G. Tight.

Fig. 1. A transverse section of the medulla a little cephalad from Fig. 3, Plate XVI.

a. Entrance of VIIIth nerve.
b. Nucleus of VIIIth nerve root.
c. Deiter's nucleus.
d. Nucleus of VIth nerve.
e. Olivary body.
f. Genu of VIIth nerve.

Fig. 2. A transverse section of the medulla taken at the entrance of the VIIth and VIth nerves,

a. Entrance of the VIIth nerve.
b. Genu of the VIIth nerve.
c. Entrance of fibres of VIth nerve.
d. Nucleus of VIth nerve.
e. Olivary body.
f. Deiter's nucleus.
g. Internal nucleus of VIIIth nerve.

Fig. 3. A transverse section of the medulla and cerebellum taken at the entrance of the caudad bundle of the Vth nerve.

a. Fibres of Vth nerve.
b. Motor nucleus of Vth.
c. Sensory nucleus of Vth nerve.
d. Olivary body.
e. Cephalad extension of internal nucleus of VIIIth nerve.
f. Spur from Deiter's nucleus. Fig. 3 is reduced somewhat below the size of the other figures in order to show the form and arrangement of the cross-section of the cerebellum.

Fig. 4. Magnified view of cells from the motor nucleus of Vth nerve, Fig. 3-*b*.

Fig. 5. A cluster of cells from the nucleus of the VIth nerve, Fig. 2-*d*.

PLATE XVIII.

W. G. Tight.

Fig. 1. A transverse section of the medulla taken at the entrance of the Vth nerve.

a. Root of Vth nerve.

b. Motor nucleus of Vth nerve.

c. Sensory nucleus of Vth nerve.

d. Nucleus of pons.

e. Dorsal longitudinal bundles.

f. Pyramidal tract.

Fig. 2. Magnified view of cells from the olivary body. Plate XVII *e*, Fig. 2.

Fig. 3. A transverse section of the medulla at the entrance of the fourth nerve. in the region of the valve of Vieussens.

a. Nucleus of the pons,

b. Cell cluster in the median gray mass.

c. Dense group of small cells in the median gray mass.

d. Decussation of IVth nerve.

e. Root of IVth nerve passing cephalad to its nucleus.

f. Dorsal longitudinal bundles.

g. Pyramidal tract.

Fig. 4. Magnified cells from the nucleus of the pons, (VI.*c*-28-*a*.)

Fig. 5. Magnified cells from central gray mass taken at *b*, Fig. 3.

Fig. 6. A longitudinal vertical section taken near the side of the medulla and embracing the lateral portion of the cerebellum.

a. Root of Vth nerve.

b. Inferior peduncle.

c. Root of VIIIth nerve.

d. Nucleus of VIIIth nerve.

Fig. 7. Magnified cells from the central gray mass, taken at *c*, Fig. 3.

PLATE XIX.

C. L. Herrick.

Fig. 1. Vertical longitudinal section of the hemisphere through the lateral part of the optic chiasm. *Pd.* Peduncular fibres in the corpus striatum. *Ac.* Anterior commissure. *Ol. tr.* Olfactory tract. *O. tr.* Optic chiasm. *y.* Nucleus above the ventral tract. *z.* isolated tract in the thalamus. *c. st.* Stratum zonale *Ftr.* Descending tract of the nates. *Np.* Peduncular nucleus. *V.* Upper nucleus of trigeminus *VI.* Lower nucleus of trigeminus. *VII.* Root fibres of facial nerve. *X.* Nucleus of auditory nerve.

Fig. 2. Horizontal longitudinal section at the level of the third roots and anterior commissure. Anterior portion from a section a little higher than the remainder. *C.s.* Corpus striatum. *a.c.* Anterior commissure. *o.t.r.* Olfactory tract, *f.* Fornix tracts. *Pd.* Peduncular tracts radiating to the corpus striatum. *f.* Fornix fibres passing dorsad. *c.g.* Corpus geniculatum. *III.* Nucleus of oculo-motor nerve. *IV.* Nucleus of pathetic nerve. *n.* Interpathetic nucleus. *VI.* Motor nucleus of trigeminus. *B.c.* Bladder cells of trigeminus. V. Tract of trigeminus from aqueduct, etc. *VII.* Caudad nuclei of the trigeminus. *Vr.* Root fibres of trigeminus. *h.* Cut section of dorsal tract to hemispheres. See Fig. 1, *L. tr.*

Fig. 3. Cells from the pons nucleus near its caudad portion on the left side. The arrow points backward.

Fig. 4, A portion of the two nuclei of the fifth, corresponding to the point at *Bc.* Fig. 2, but on the opposite side, *a* illustrates the motor, *b* the bladder cells. The arrow points backward. Both are drawn to the same scale with camera lucida from the section shown in part in Fig. 2.

Fig. 5. Cells from nucleus of facialis to show the processes.

Fig. 6. Semi-diagramatic section perpendicularly through the four outer layers of the nates, including the outer part of the tectum.

ERRATA.

Page 25, seventeenth line from top, read County, instead Connty.
Page 25, fifth line from last, a period after abundant.
Page 25, fourth line from last, a comma after this.
Page 25, second line from last, read, *Prœtus haldemani.*
Page 26, thirteenth line from last, read, *Allorisma consanguinata.*
Page 26, tenth line from last, read, *Spirifer striatiformis.*
Page 27. eighteenth line from top, read, 18 inches.
Page 27, eleventh line from last, read, *Syringothyris.*
Page 28, tenth line from top, read, *Hem. crenistria.*
Page 28, eighth line from last, read, *Syringothyris carteri.*
Page 28, last line, read, *Poisidenomya.*
Page 29, fifteenth line from last read, *Syringothyris carteri.*
Page 29, fifth line from last, read, alternating shales.
Page 30, eighteenth line from last, read, *Syriopecten nodocostatus*, and *Chœnetes tumida.*
Page 30, last line, read, *Hemipronites crenistria.*
Page 31, twentieth line from last. read, *Solenomya cuyahogensis.*
Page 31, nineteenth line from last, read, *Macredon tenuistriata.*
Page 33. eleventh line from top, read, *Taxicrinus communis.*
Page 33, sixteenth line from top, read, *Decadocrinus pleias.*
Page 34, seventh line from top, read, *Palæoneilo truncata.*
Page 34, fourth line from last, read, *Prœtus haldemani*

[The author of the papers, "The Waverly Group" and "Tabulated List of Fossils," not having read the proofs, should be exonerated from mistakes in typography.]

Page 38, 4th line from bottom. For *Protyon* read *Procyon.*
Page 41, 18th line from bottom. For *thalmus* read *thalamus.*
Page 42, 9th line from top. Reverse position of *commissure posterior.*
Page 45, 14th line from top. For *restiform* read *restiforme.*
Page 49, 1st word. For *arber* read *aber.*

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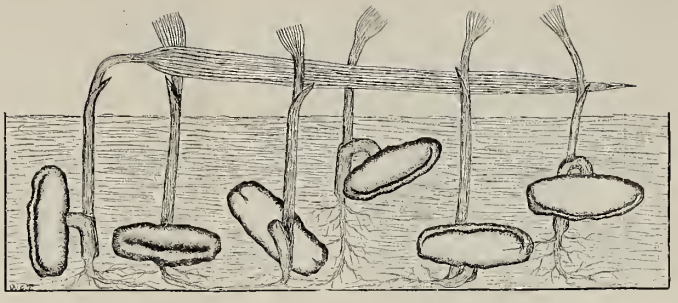

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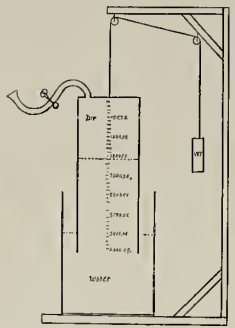

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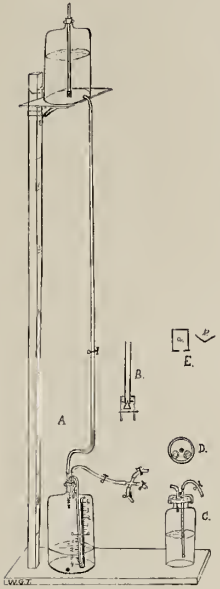

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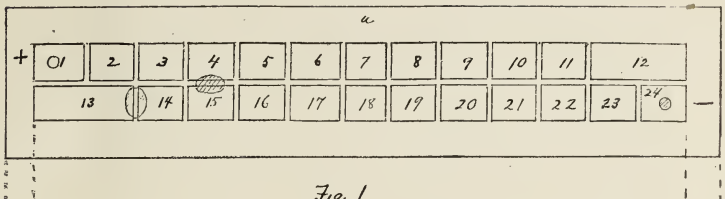

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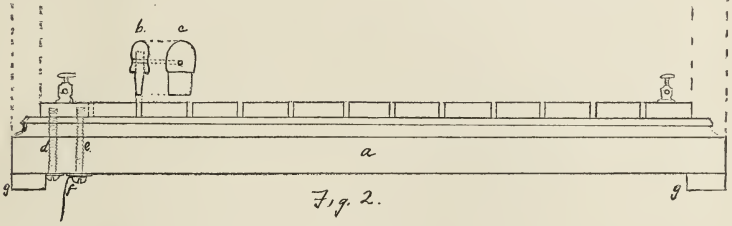

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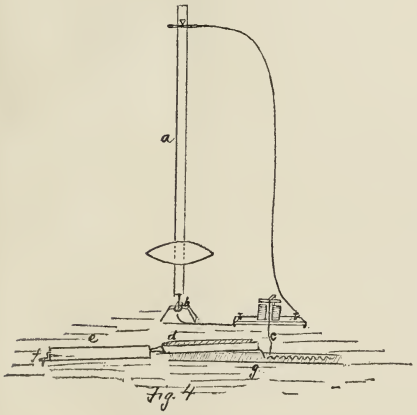

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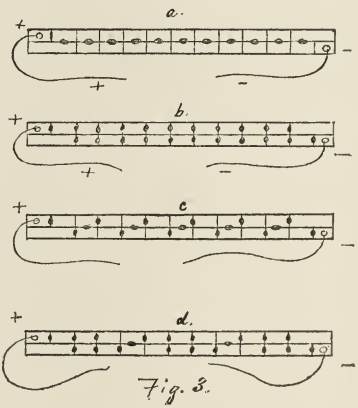

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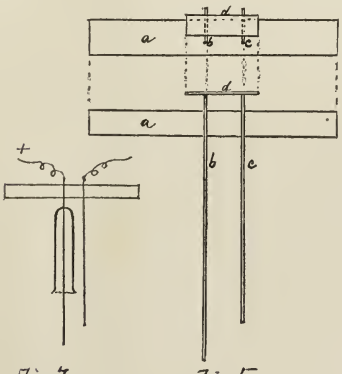

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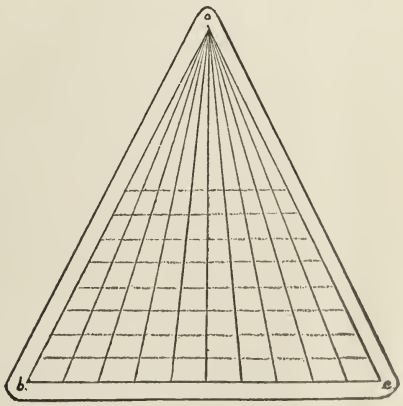

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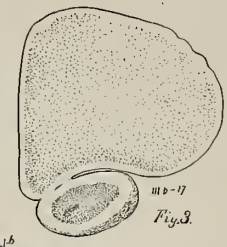

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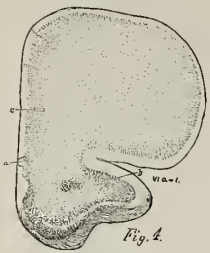

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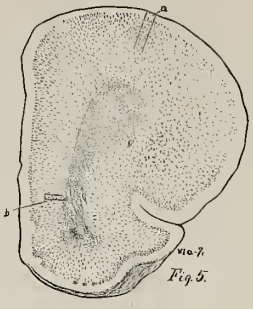

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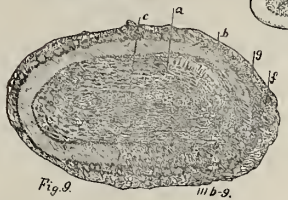

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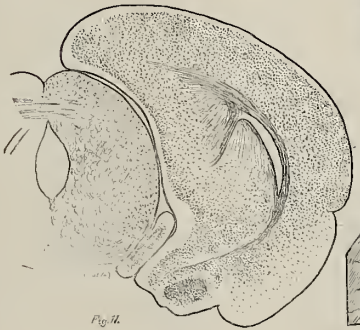
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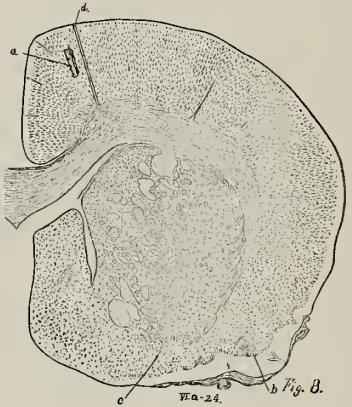

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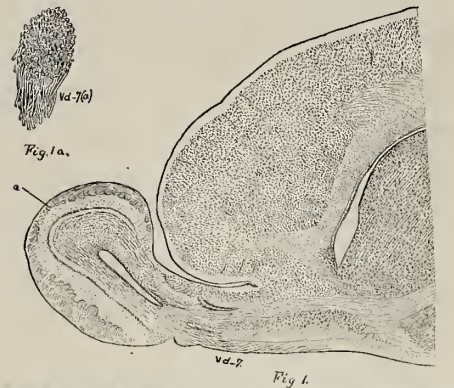

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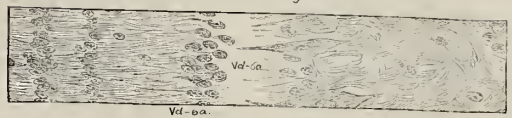

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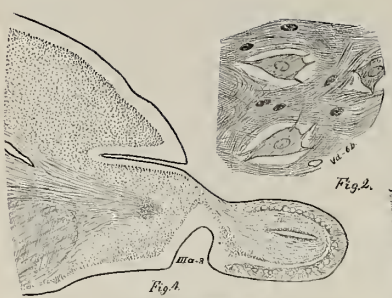

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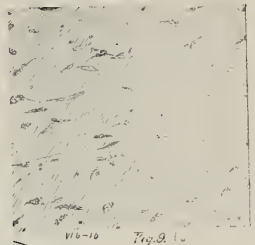

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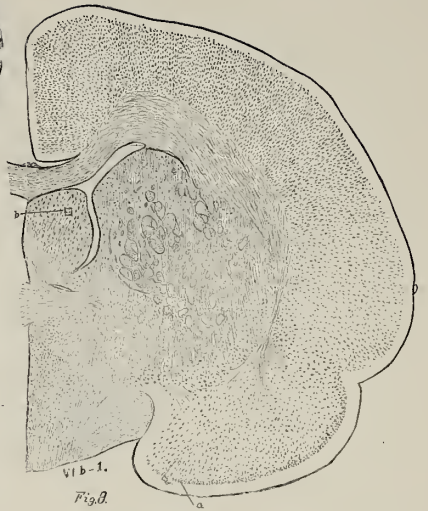

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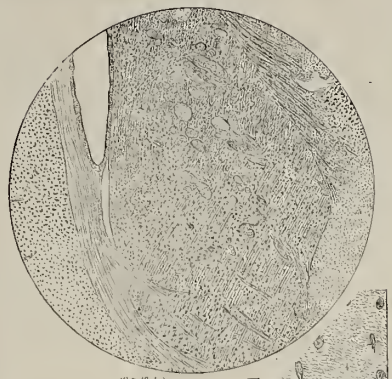

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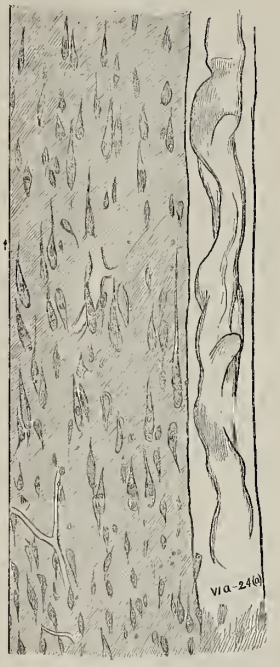

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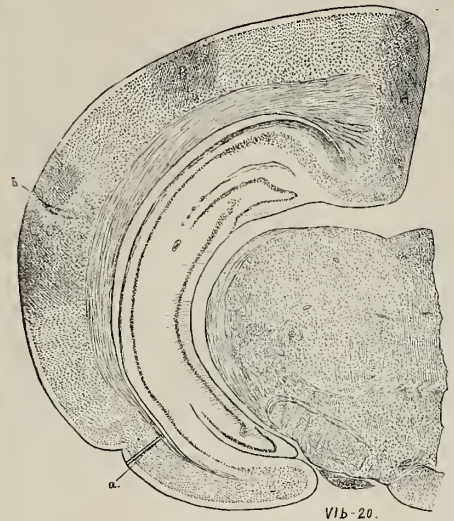

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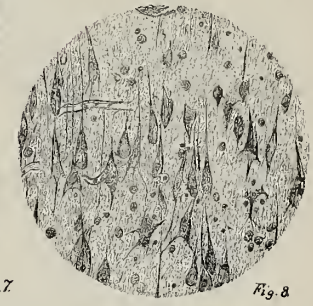

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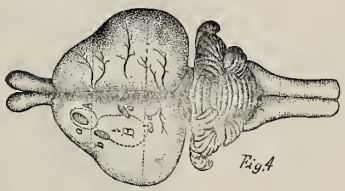

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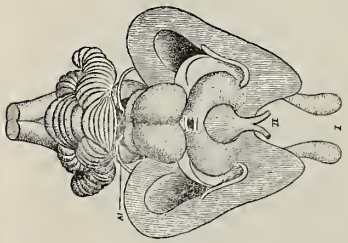

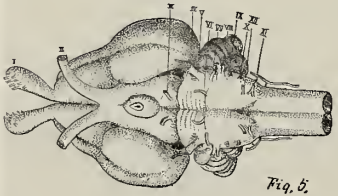

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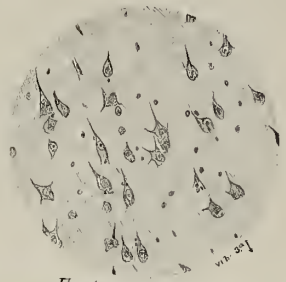

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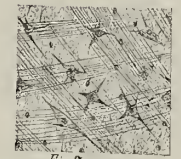

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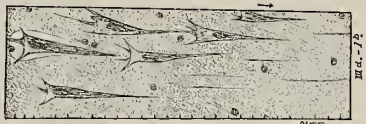

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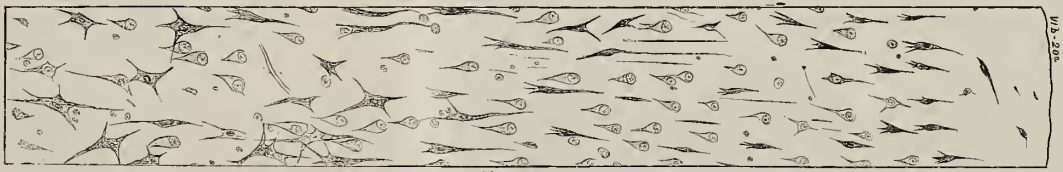

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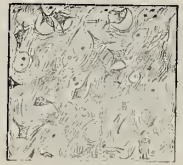

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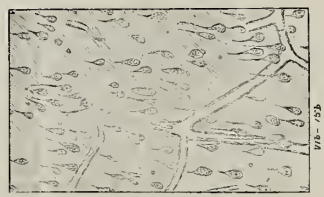

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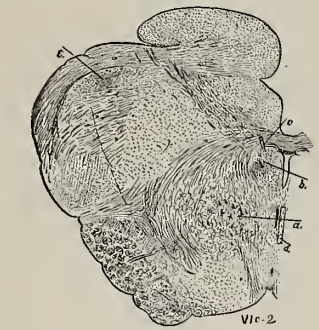

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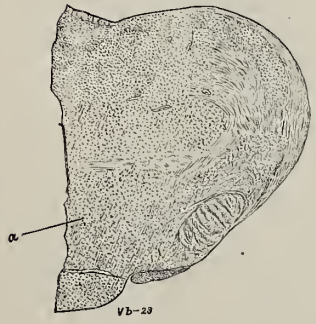

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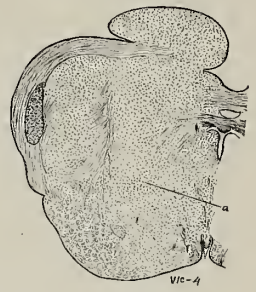

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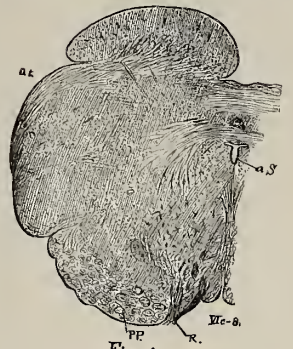

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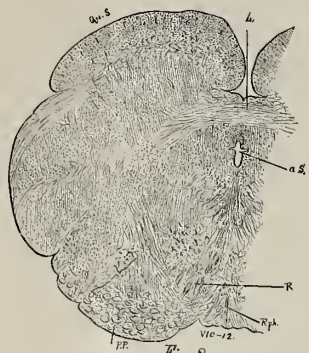

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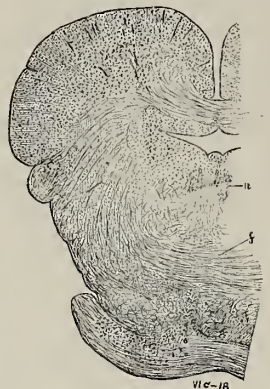

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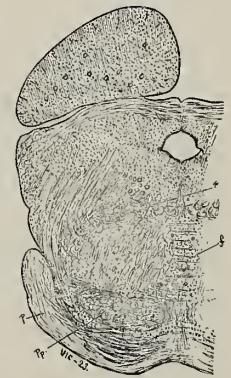

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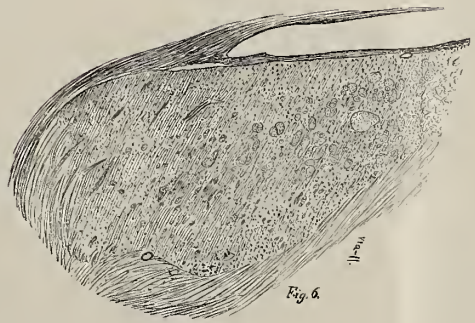

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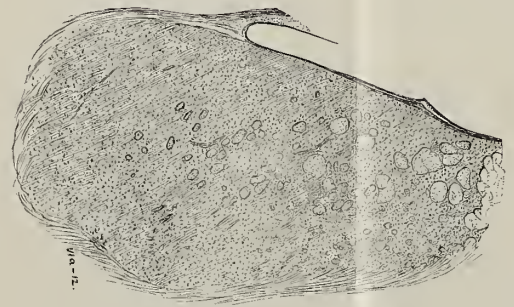

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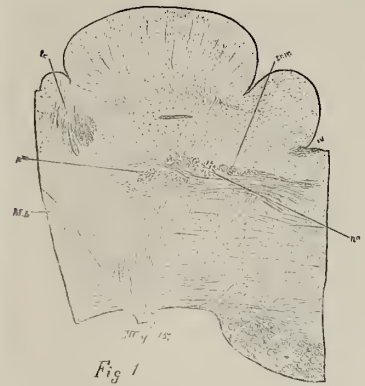

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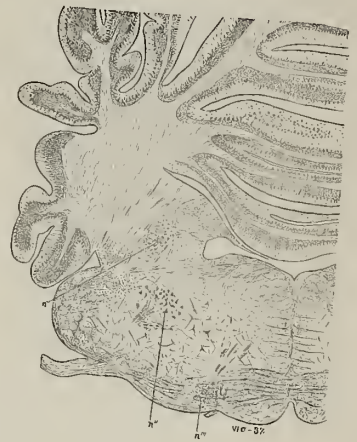

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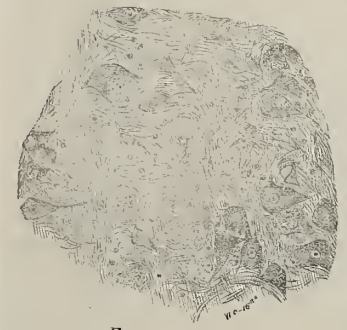

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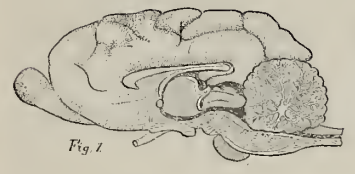
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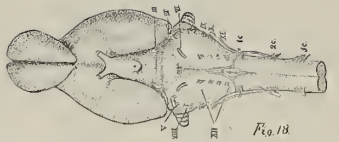
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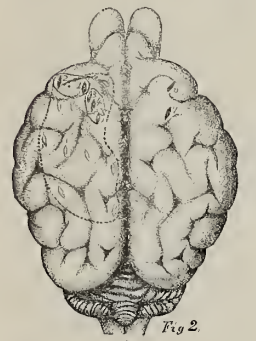
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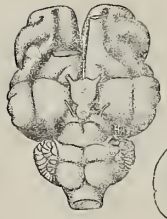
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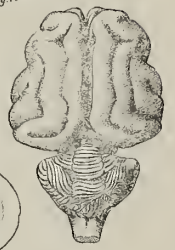
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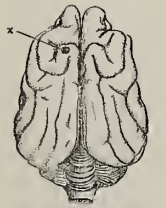
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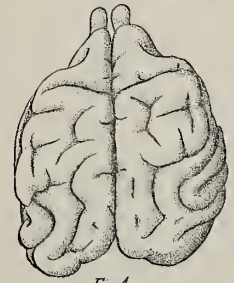
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Fig. 12.

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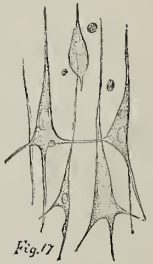
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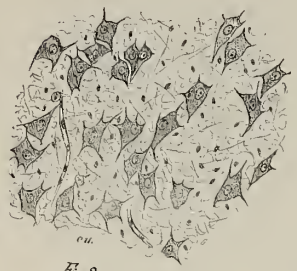

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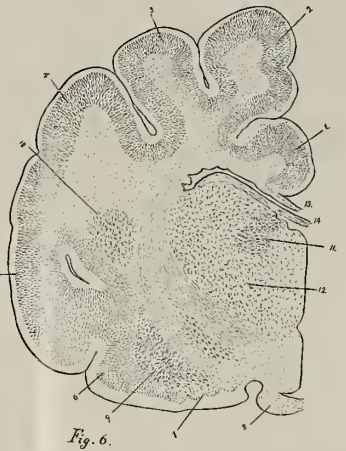

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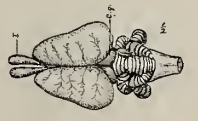

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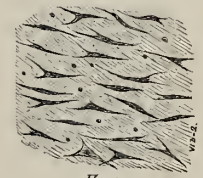

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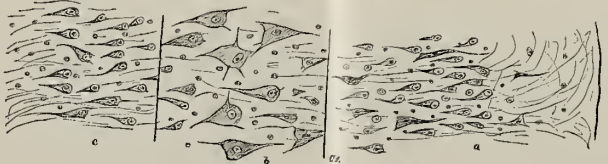

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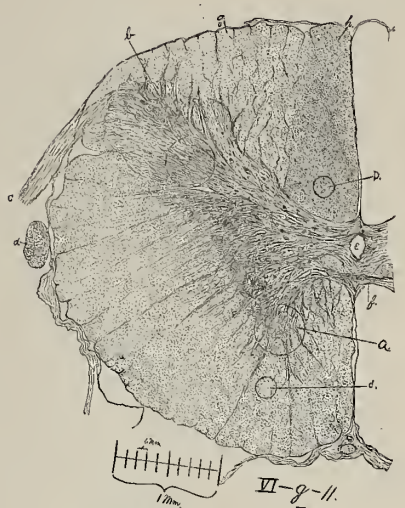

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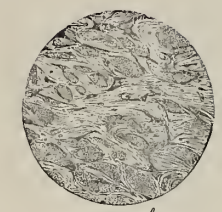

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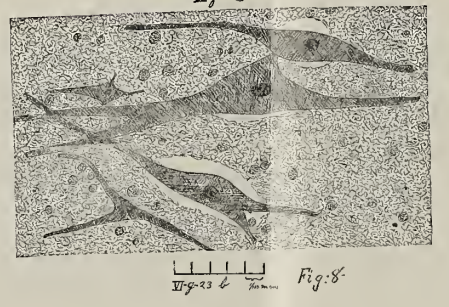

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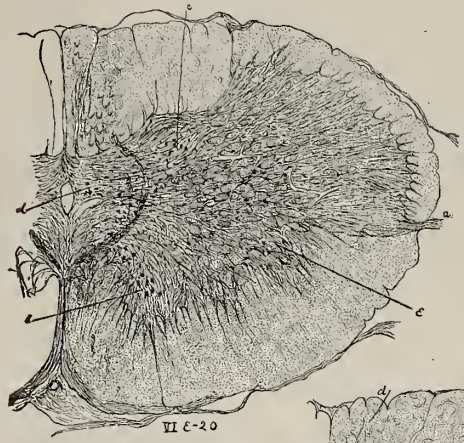
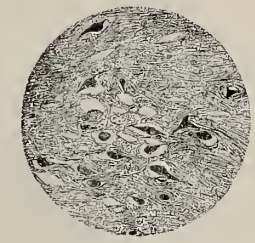


Fig. 1

Fig. 2 VI-E-16-a

Fig. 3. VI-E-18-C



VI E-14-d

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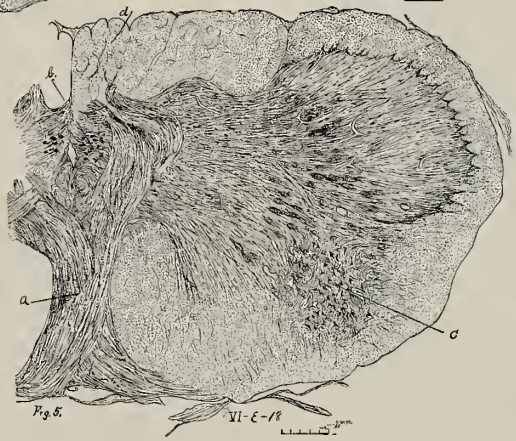
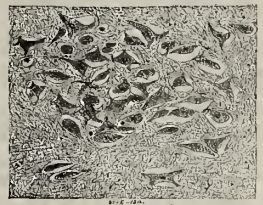


Fig. 5. VI-E-18

VI-E-16

Fig. 6



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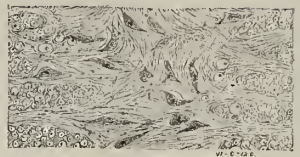

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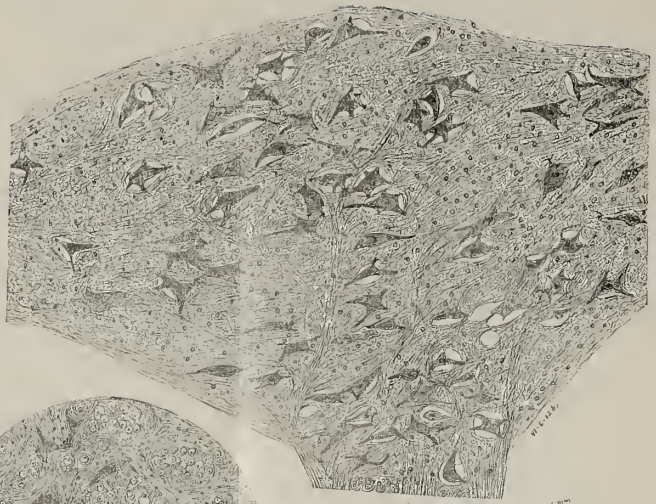


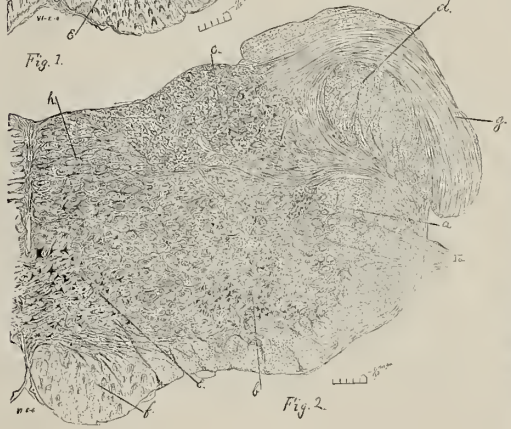
Fig. 5.

Fig. 1.

Fig. 4

Fig. 6.

Fig. 1.



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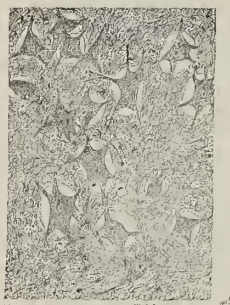

Fig. 4.

Fig. 5.

Fig. 6.

d.
c.
b.
a.
VI-C-61.
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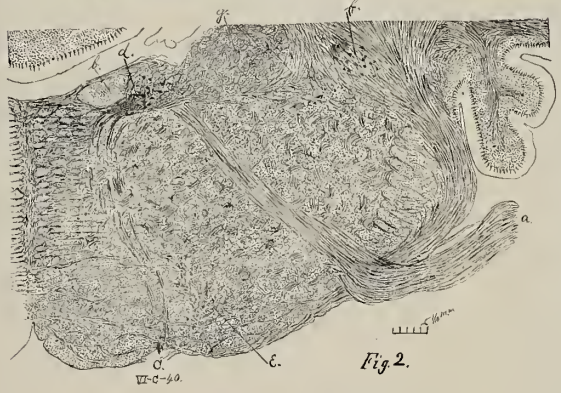
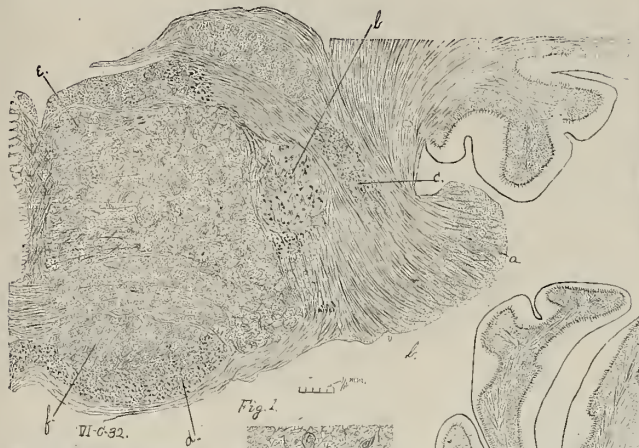

d.
a.
c.
VI-C-40.
Fig. 2.

c.
a.
b.
d.
VI-C-37.
Fig. 3.

Fig. 4.

Fig. 5



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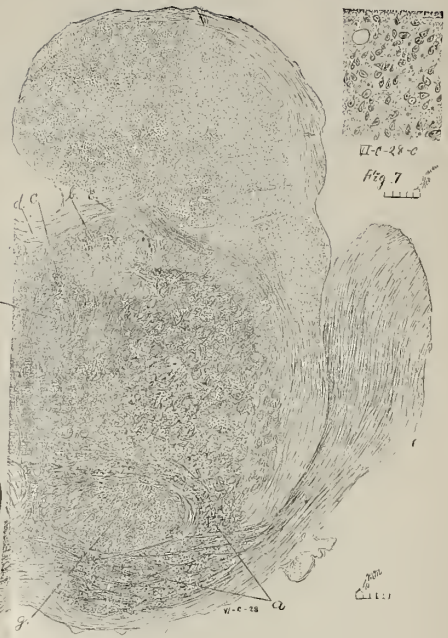

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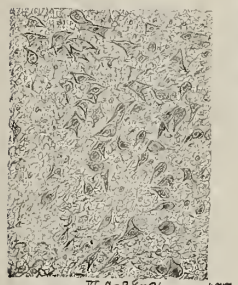

Fig. 4.

Fig. 5.

Fig. 6.

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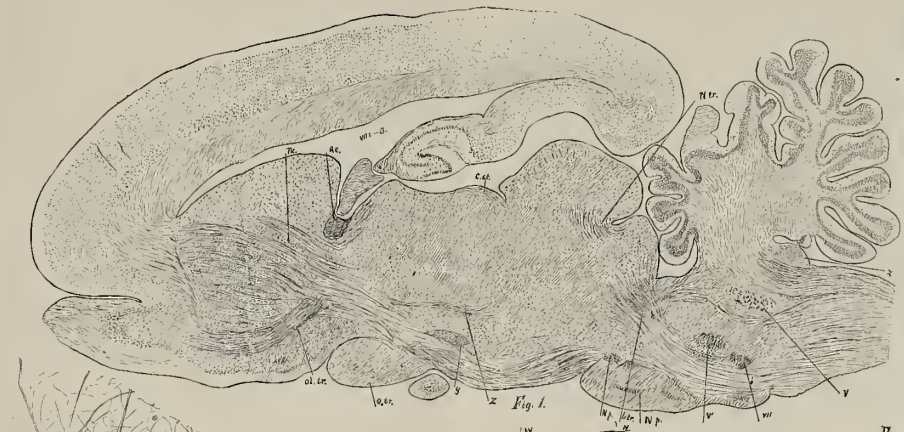

Fig. 3.

Fig. 6.

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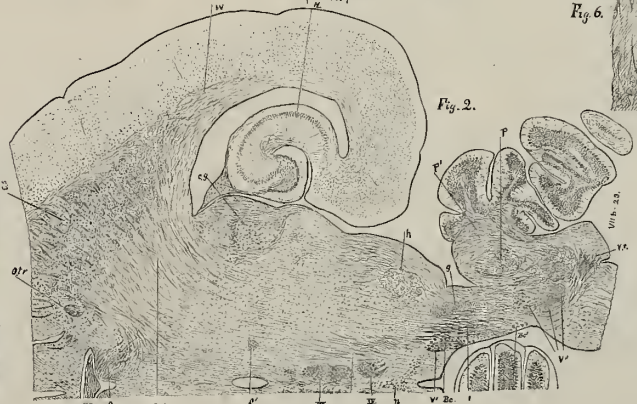

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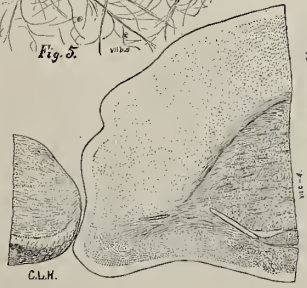
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BULLETIN

OF THE

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EDITED BY

W. G. TIGHT, M. S.,

DEPARTMENT OF GEOLOGY AND NATURAL HISTORY.

VOLUME V.

WITH TWENTY-ONE PLATES.

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GRANVILLE, OHIO, JUNE, 1890.

PUBLISHED MONTHLY. COMMENCED JANUARY 1888.

The American Geologist,

ILLUSTRATED.

A strictly Geological Journal.

Two volumes of 400 pages each, per year,

Subscription $3.50 Per Year.

All back numbers and the subscription for 1890, $8.00.

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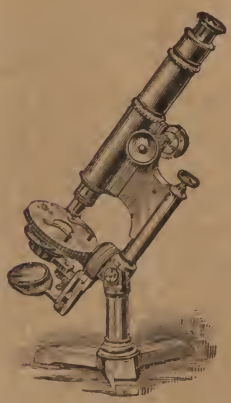

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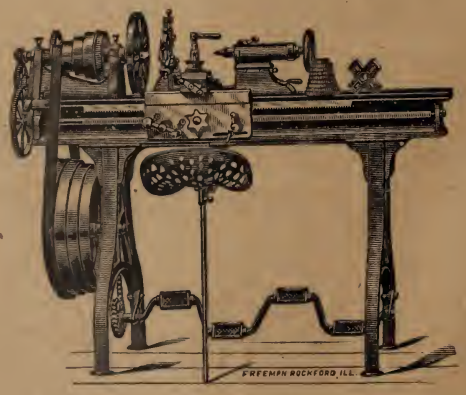

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